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GENERAL CHARACTERISTICS OF AQUATIC MACROPHYTE ASSOCIATIONS IN THE UPPER POPLAR RIVER DRAINAGE OF NORTHEASTERN MONTANA

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GENERAL CHARACTERISTICS OF AQUATIC MACROPHYTE ASSOCIATIONS IN THE UPPER POPLAR RIVER DRAINAGE OF NORTHEASTERN MONTANA

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BACKGROUND INFORMATION

DESCRIPTION OF THE CORONACH POWER GENERATION DEVELOPMENT

The initiation of the macrophyte investigation that is described in this report for the upper Poplar River region in Montana is related to a series of events that have recently culminated in the development of a power generating complex in the Saskatchewan segment of the Poplar basin. As a first step, the Saskatchewan Power Corporation (SPC) applied to the Saskatchewan government in March of 1972 for water rights on the East Poplar River, and a reservation of 6,000 acre-feet of water per year was subsequently granted to this corporation. In late 1974, the SPC then proposed the construction of a 300-megawatt, coal-fired electrical generating station in the East Poplar drainage about eight miles north of the United States-Canadian border and approximately 23 miles north of Scobey, Montana. This unit was scheduled to go on line before 1980, and the SPC proposal also pointed to the possibility of constructing one to three additional units at some future date if and as the need for extra power might happen to arise in the Province. Lignite coal that can be mined in the vicinity of the plant would serve as the source of fuel to operate the generators, and water for the station's flow-through cooling system would be obtained from a 32,000 acre-feet impoundment (Cookson Reservoir and Morrison Dam) that would be located on the East Poplar River near the town of Coronach, Saskatchewan (Davis and Pike, 1976; Cohen and Smith, 1978; and Tennant and Loch, 1979).

Following the completion of various environmental assessments related to the proposed generation project, along with the requisite public and official hearings, approval for the construction of the dam and the generating station was given to the SPC by Canadian authorities during the early months of 1975. The building of these facilities was started in 1977, and the reservoir basin became completely filled with water in March of 1979; the power plant then became operational a short time thereafter. Since the East Poplar River is an international and transboundary stream, the license issued to the SCP for their power plant facilities is subject to the conditions that are imposed by the Boundary Waters Treaty of 1909 and by the Canadian International River Improvements Act. Such limitations include the water-use restrictions that were developed through an international apportionment of waters in the Poplar basin by the International Joint Commission (Cohen and Smith, 1978). This apportionment essentially divided the available water in the drainage between Canadian and United States interests for use on both sides of the border.

ENVIRONMENTAL EFFECTS

The SPC development in southern Saskatchewan caused a great deal of concern in northeastern Montana relative to the likelihood of adverse environmental impacts stemming from the operation of the generating plant and its associated strip mining and reservoir facilities. The major causes of the impacts that were projected to occur from the Coronach complex can be summarized as follows (Tennant and Loch, 1979): (1) the disruption of aquifers as a result of the mining activities; (2) the occurrence of wind-borne stack pollutants; (3) the introduction of toxic and harmful substances via ash slurries and anti-corrosive additive substances; (4) the advent of increased concentrations of dissolved materials in the Cookson outfall and downstream in the East Poplar River because of natural and forced reservoir evaporation with the latter resulting from the flow-through cooling system; and (5) the reduction of total stream flows and (6) an alteration of stream flow patterns within the basin. All of these features could adversely affect the aquatic biota of the Poplar River drainage and impact the offstream uses of its water. More specifically, the final two listings that were presented previously would most likely cause an alteration in the East Poplar's morphological attributes and an alteration in its bedload transport characteristics, and these changes would undoubtedly produce some deterioration in the different types of habitats that happen to be utilized by the various macro- and microorganisms residing within, on, or near these flowing waters.

In response to these impact identifications, a number of biological, hydrological, and water quality investigations were initiated in the Poplar region by various agencies in order to describe the biotic, environmental, and water-use components of the drainage and to obtain baseline information for future comparative studies. In addition, some of these investigations were designed to more clearly assess and evaluate the types and magnitudes of impacts that might be expected for the area, providing a basis for making recommendations on management options that could act to lessen the severity of these effects. As a result, the macrophyte inventory presented in this report represents only one effort in a number of research projects that have been completed or are still ongoing in the Poplar basin.

REVIEW OF PREVIOUS INVESTIGATIONS

GENERAL ASPECTS

Subsequent to the granting of a permit by Canadian authorities to the SPC to allow the construction of the Coronach power generating station and its ancillary facilities, five committees proficient in particular technical areas were established via the International Joint Commission (IJC) to answer any questions that might happen to arise concerning the transboundary effects of the Coronach project and concerning the water quality and other impacts of the apportionment recommendations that were to be formulated by the Poplar River Task Force. This latter group was indirectly appointed by the IJC to undertake the apportionment task, and a Biological Resources Committee (BRC) was organized to consider the biotic implications of their apportionment recommendations and the SPC development (Tennant and Loch, 1979). The IJC, in turn, had the responsibility for arriving at an equitable apportionment decision based on the recommendations of these entities. In the meantime, a number of investigations had been started in the Poplar

River system, both in Saskatchewan (Cullimore, 1975) and in Montana, and these efforts provided the baseline data and information that was necessary so that the Poplar River Task Force and the five committees could complete their missions.

Poplar River studies that were conducted in the United States include, as examples, stream flow and water quality monitoring (United States Geological Survey, 1975-1979), water quality evaluations (Klarich, 1978), algal assessments (Bahls, 1977), fishery inventories (Needham, 1976; Stewart, 1979), and wildlife surveys (DeSimone, 1979 and 1980). Using this type of information and the Poplar River Task Force apportionment recommendations which were published in 1976 (Davis and Pike, 1976), the BRC ultimately compiled a final report for the IJC that consisted of biological resource descriptions, impact predictions and assessments, and various recommendations (Tennant and Loch, 1979). The findings of this committee in relation to the aquatic macrophyte communities of the East Poplar River then led to the initiation of the additional study that is described in this report.

In spite of the many biological investigations that were conducted in the Poplar River basin, no quantitative evaluations have been made of the aquatic macrophyte communities in either the Canadian or the United States portions of the drainage, and no direct measurements have been taken of the physical requirements of these plants. Taxonomic collections and identifications have been obtained from the East Poplar River in Saskatchewan (e.g., Baron, 1974), and a reconnaisance survey of the higher aquatic plants in the upper East Poplar in Montana was completed by the BRC. Also, infrared aerial photographs of the East Poplar have been examined by DiSimone (1980) to document the distribution and extent of emergent vegetation in the stream. But because of the overall paucity of macrophyte information, the BRC concluded there " . . . is insufficient information on aquatic macrophytes in the Montana section of the East Poplar River for a rigorous assessment of water quality and water quantity impacts (Tennant and Loch, 1979)." Nevertheless, some general impact assessments were put forth by this committee.

BIOLOGICAL IMPACT EVALUATIONS AND RECOMMENDATIONS

The impact predictions that were eventually formulated by the BRC in relation to the macrophyte communities of the East Poplar River basically revolved around the hydraulic changes that were calculated to occur in the river below the reservoir as a result of an upstream water loss and stream regulation by Morrison Dam. Such hydraulic alterations would be reflected in fairly significant reductions of river width, depth, current velocity, and discharge, and these changes were projected to lead to a general entrenchment, further development, and downstream expansion of the East Poplar's macrophyte associations. These predictions coincide with the observation of Davis and Brinson (1980) that extensive aquatic plant beds can develop downstream of an impoundment depending upon the dam's discharge characteristics. The committee further stated that such an enhancement of macrophyte biomass in the East Poplar could conceivably produce " . . . up to a 50 percent reduction in population size of waterfowl . . . due to habitat alteration . . . (Tennant and Loch, 1979)."

Because of the need for reservoir filling during high flow periods, such macrophyte buildups below a dam are at least in part related to a dampening of the spring runoff phase or freshet and the subsequent loss of a stream's scouring or "cleansing" capacity that occurs during the high flow portion of the hydrological cycle. The BRC, thereby, in addition recommending the release of relatively significant quantities of water throughout the year (at least three cfs in an average or above average water year), also proposed the release of at least ten to fifteen cfs during the spring months of April and May plus a peaking flow that would approach 620 cfs and develop over a period of several days in order to simulate the spring freshet that acts to curtail excessive aquatic macrophyte blooms. The BRC also recommended the conduction of a rigorous macrophyte survey of the upper Poplar River drainage in Montana using transect methods in order to fill the biological data void that was largely left open by the earlier investigations. This latter recommendation then points to the purpose of this more recent research effort.

STUDY OBJECTIVES

In view of the distinct lack of information dealing with the aquatic plant communities of the upper Poplar River drainage, one of the obvious objectives of this particular investigation was to describe the general characteristics of these communities in terms of their species compositions, the relative abundances of the different plant taxa, the taxa's growth habits (whether emergent, submersent, or amphibious), their reproductive status (whether vegetative or flowering-fruiting), and the general structure of the macrophyte associations. In addition, supplemental data were to be obtained that would outline the physical and chemical aspects of the aquatic systems that sustain these plants, i.e., the depth of water and its current velocity, the nature of the substrate or stream bottom, the degree of light penetration, salinity levels, nutrient availability, and so on. Of course extensive data on the chemical features of the Poplar drainage streams are now at hand as a result of the monitoring efforts by the United States Geological Survey (1975-1979) in the region, and the obtainment of specific physical numbers was therefore of primary importance in relation to the macrophyte work.

With the availability of physical and chemical data in conjunction with information describing plant abundances at various stream locations, assessments can then be directed towards a determination of which of the environmental factors are influential in defining distributional trends and which of the factors are most crucial in delimiting particular plant species. But because of time constraints, this report will principally describe the general characteristics of the Poplar plant communities. Hopefully funding and manpower will eventually become available so that a more extensive factor analysis can be completed for the aquatic macrophytes of the project region. Requisite data for this type of evaluation are now available as a result of this present study.

Another objective of this project, as recommended by the BRC (Tennant and Loch, 1979), was to provide a core of baseline or "time zero" macrophyte data at definite locations on the applicable Poplar streams that would then be available for use in future comparative studies at the same sampling stations. In this fashion, documentation can be obtained in relation to the occurrence, extent, and nature of any changes that might develop in the higher plant communities of the Poplar basin because of the SPC development and stream regulation by Cookson Reservoir. Although this initial baseline investigation was undertaken somewhat "after the fact," i.e., about two years after the closing of Morrison Dam, this delay does not appear to have had an adequate duration so as to totally invalidate the obtainment of reliable information that can be used in such time-based comparisons. This is due to the fact that any successional changes that might occur in the plant communities of the East Poplar would be expected to gradually develop over a fairly extended period of time before a new vegetational climax is finally achieved. Therefore, any alterations that might have occurred in the two intervening years between dam closure and this baseline study would not be anticipated to be so extreme as to totally obfuscate the recognition of any sequential variations and trends. Thus the data obtained in this initial survey effort should be valid for an application to future evaluations of this kind.

The ultimate fulfillment of the additional study objective described in the previous paragraph will be dependent upon the availability of subsequent funding and manpower with which to conduct the follow-up macrophyte sampling efforts in the Poplar region. As suggested by the BRC, these follow-up investigations should be conducted at three-year intervals after the establishment of the baseline data pool. Further recommendations of this kind that were specifically developed from this current project will be presented in this report.

DESCRIPTION OF THE STUDY AREA

As illustrated by Figure 1, the Poplar River originates as three distinct forks with their headwaters in the semi-arid regions of south-central Saskatchewan. The three forks of the river, the West, Middle, and the East Poplar, separately cross the international boundary and join at two locations near Scobey, Montana to form the main Poplar River, and the mainstem, in turn, flows into the Missouri River near Poplar, Montana. The SPC generating station is located on the East Poplar near the town of Coronach, Saskatchewan and in the general vicinity of the recently developed Cookson Reservoir. This area of Saskatchewan and northeastern Montana is generally characterized by a continental climate with cold and dry winters, warm and dry summers, and with a moderately warm and relatively wet spring period (Tennant and Loch, 1979). Physically, the streams of the basin have low-gradient and sinuous water courses that are made up of long, large pools connected by widely separated, restricted, and shallow riffle reaches. Sand, silt, and muck-mud bottoms occasionally intermixed with gravels are commonly found in the pools, while gravels and boulders are the common stream bottom materials of the riffle segments.

Although having a total drainage area of approximately 3,300 square miles, surface water is a comparatively scarce commodity in the Poplar basin with droughts a common occurrence in the region. The average annual natural flow of the drainage at the United States-Canadian border equals about 35,000 acre-feet while that at the mouth of the river equals approximately 100,000 acre-feet per year. The streams of the drainage generally have rather high spring flows resulting from snowmelt or snowmelt augmented by spring rainfall, and these spring freshets, which last for only around ten to twenty days, account for nearly three-fourths of the streams' total annual discharge. These high spring flows then rapidly recede to the small and often insignificant flows that define the low water availabilities of

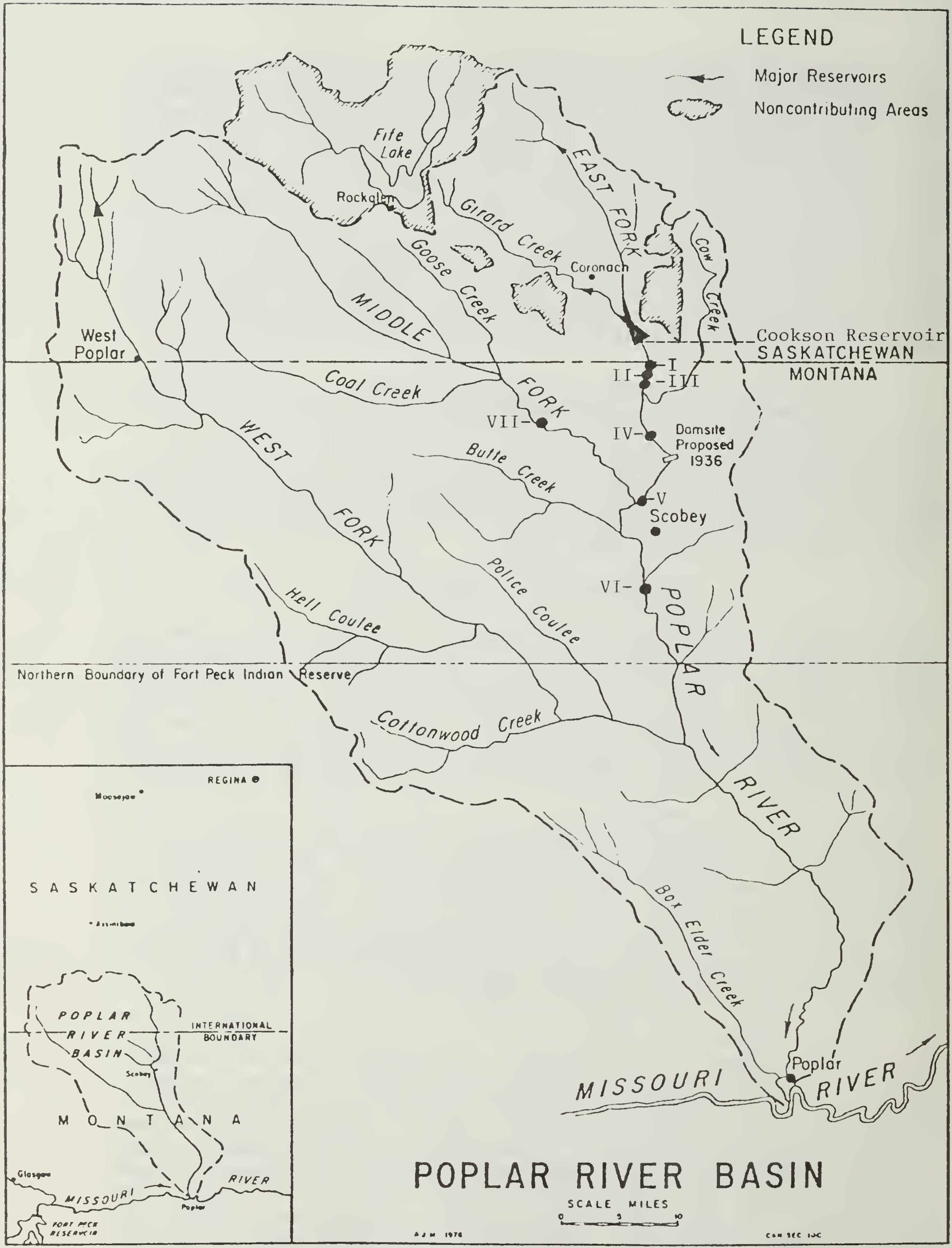

Figure 1. Map of the Poplar River drainage showing the general locations of the seven (I to VII) macrophyte sampling stations. Map taken from the International Joint Commission.

the summer, fall, and winter months (Cohen and Smith, 1978). For the most part, the study area lacks an adequate supply of water to satisfy all of the surface demands, and this then points to the crux of a continuing debate for water between instream and offstream applications such as the maintenance of the basin's walleye and northern pike sport fishery versus the various consumptive needs for water as exemplified by the requirements of the SPC complex.

Even though water is not particularly plentiful in the Poplar basin, its streams are somewhat unique to a prairie setting in Montana by being able to support an excellent warm-water fishery (Needham, 1976). At least 28 species of fish inhabit the Poplar River in Montana, and about 45 species of waterfowl also use the stream during various seasons of the year as well as a number of other bird species, mammals, and other poikilotherms (Tennant and Loch, 1979). But as stated by Needham (1976), while " . . . habitat in the Poplar River is of sufficient quality to maintain a sport fishery, only a small difference in habitat separates this river from numerous other streams which support only non-game species." Thus the Poplar system appears to be in a position to be fairly easily degraded through the application of comparatively minor environmental alterations. As a result of these features, a great deal of attention has been focused on the biota of the Poplar drainage in light of the potential impacts that might arise from the Coronach development with its extensive water demands.

FIELD PROCEDURES AND SAMPLING PROGRAM

APPRAISAL SITES

Observations by earlier investigators in the Poplar River drainage indicate that aquatic macrophytes are most prevalent in the East Poplar River, particularly in its upper reaches, while being largely insignificant components of the main Poplar and the West Fork of the river (Tennant and Loch, 1979). Brief surveys that were conducted on the lower river as a part of this recent project also pointed to the lack of obvious macrophyte growths in the lower segments of the basin. In contrast, some macrophytes were observed to occur in the Middle Fork of the river, but these plants were not found at the abundance levels that characterize the more eastern stream. Because of these features, and because of the fact that the SPC generating complex is located on the East Poplar, the primary focus of this macrophyte assessment effort was directed to the aquatic plant communities that reside within the East Poplar waters.

As indicated in Figure 1, five of the seven macrophytes appraisal sites were placed on the East Poplar River, and three of these stations (I, II, and III) were located in close proximity of each other and in close association with the international boundary and Cookson Reservoir. These stations were located in this fashion because detectable increases in macrophyte abundance were expected to occur most rapidly in the more upstream reaches of the river that are in close juxtaposition to the East Poplar impoundment. Thus fairly complete descriptions of the macrophyte communities in these particular sections of the stream were deemed to be especially important in terms of any future comparative work.

The other two stations (IV and V) on the East Poplar were more widely spaced and were located on the lower reaches of the stream in order to describe the communities in this segment of the river and in order to be able to monitor the expansion of any macrophyte enhancements into these downstream sections. In addition, one station (VI) was located further downstream on the main Poplar below the confluence of the Middle Fork to serve as a control station and to provide a point of comparison for the upstream sites. Also, since the Middle Fork of the Poplar River will not be directly influenced by the Cookson impoundment, a single and seventh station (VII) was placed on this particular river to afford another basis of comparison. No appraisal sites were located below station VI on the main Poplar or on the West Fork because of the general absence of aquatic plant communities in these two drainage courses.

Table 1 presents the specific geographic descriptions of the seven macrophyte sampling sites in the Poplar drainage using the township (T), range (R), section (numbers 1 to 36), and quarter, quarter-quarter, and quarter-quarter-quarter section (letters A to D) designations that are prescribed by the Bureau of Land Management. A more detailed explanation of this method of describing geographic locations is available in Klarich (1978).

MACROPHYTE ASSESSMENTS

Introductory Considerations

Three macrophyte sampling trips were undertaken during the summer of 1980 to each of the seven macrophyte assessment stations listed in Table 1. These field forays were conducted in late July-early August, in late August, and in mid-September, and identical assessment procedures were used on all three of the sampling trips and at all seven of the sampling stations. The field work of the project then basically involved the collection of plant abundance, physical, and water quality data along with the collection of plant specimens for taxonomic identifications and verifications.

Both the emergent and the submersant (including the floating-leaved plants) types of aquatic vegetation were assessed during the project, and this involved only those plants that were definitely observed to be within the actual confines of the Poplar streams. No attempts were made to evaluate the vegetation that was found to be nearby but clearly outside of the edge of water demarcations. Therefore, no riparian data were obtained from the project, although the upper Poplar drainage does not exhibit the development of riparian plant communities that would closely coincide with the classical visualization of this term (Tennant and Loch, 1979).

Quantitative Features

Method Description--Theoretical Applications. As recommended by the BRC, a transect method was employed as a means of obtaining quantitative macrophyte abundance data from each of the stream locations. The basic workings of this methodology have been described by Canfield (1942), and it has been successfully utilized in an evaluation of aquatic vegetation in the Madison River drainage of Yellowstone National Park (Rasmussen, 1968; Horpestad, 1969). The application of this method first involves the stringing of a ruled transect line, e.g., a tape measure, across and above the stream perpendicular to the main thread of flow. Subsequently,

Table 1. Township (T), range (R), section (numbers), and subsection (letters) geographic descriptions of the seven macrophyte assessment sites established in the upper Poplar River drainage.

Station Symbol and Name	Geographic Location
I. East Poplar River at the IB*	T.37N, R.48E, 05AAA
II. East Poplar River near the IB*	T.37N, R.48E, 05CDA
III. East Poplar River south of the IB*	T.37N, R.48E, 08BCD
IV. East Poplar River north of Scobey	T.36N, R.48E, 03ABA
V. East Poplar River near Scobey	T.36N, R.48E, 33ACA
VI. Main Poplar River south of Scobey	T.34N, R.48E, 03CDD
VII. Middle Fork Poplar River near Four Buttes	T.37N, R.46E, 36BCC

*IB denotes the international boundary.

vertical secondary lines perpendicular to this main transect line are sequentially extended into the water at appropriate intervals along the transect, and the aquatic plants that happen to occur in the vicinity of a secondary line are recorded as being present at that particular point in the stream. The absence of any plants at a point is also noted as the occurrence of bare substrates, and more than one plant taxa can be recognized as being present at any one of the transect points.

Method Description--Field Applications. For this study, top-setting gaging rod was used to define the secondary lines because this rod also provided the option to garner physical data in conjunction with the plant assessments. The plant taxa that were observed to be in a close vicinity to this rod on a transect run were then recorded as being present at those particular locations in the stream. In addition to noting the presence of plant taxa at a transect point, or the nonoccurrence of aquatic vegetation at that location, the emergent-submersant status and the vegetative-reproductive status of any plants at the point were also described. As one modification to the standard transect approach, each of the plant taxa that were found at a given transect location were further relegated into one of three abundance categories--low, medium, or high, and this addiional application was made in order to afford a means of expanding the macrophyte abundance data base of the inventory.

As the evaluations of this kind progressed across a transect line, all of the related information was recorded on field data sheets for later data manipulations, refinements, and reductions. Ultimately, the percent occurrences of the various taxa that were identified at the different transect points of a sampling station were calculated as one of the major data expressions of the investigation. Percent canopy cover and percent relative abundance are other phrases that are often used to refer to this type of abundance elevation.

The percent occurrence value of a taxon provides some insight into the density or areal abundance features of a plant, while the low, medium, and high macrophyte abundance categories of the survey were designed to provide the capability for expressing the overall biomass features of a taxon at a particular stream location as well as a description of the vertical aspects of a plant grouping at that same particular spot. The "low" category, thereby, typically delineates the observation of a single aquatic plant of a taxa, generally laid close to the substrate, and this situation denotes the occurrence of a low biomass level and the absence of a marked verticality to the plant association at that location in the stream. In contrast, the "high" category relates to the recognition of a distinctive plant bed at a secondary transect line with a number of intercrossing and closely packed plant individuals that describe the case of a high biomass level and the case of a definite vertical posture in the plant association. The "medium" category then provides for an intermediate option between these two extremes. The quantification of these three abundance classes in relation to the percent occurrence calculations of the project will be outlined in a later section of this report.

Transect Characteristics. Each of the transects that were run across the study area streams basically consisted of two kinds of transect points: the two secondary lines that were located at the edge of the water on both sides of the stream, initiating and terminating a transect run, plus a number of instream points whose number and interval distances generally depended on the width of the river at the transect locations. For the narrower reaches in the vicinity of 25 feet across or less, plant evaluations were typically run at one or two foot intervals, but for the wider stream segments approaching 60 or 70 feet, interval distances between any two transect points often ranged between three and five feet. As a general study guideline in this regard, an attempt was made to assess a minimum of twelve points along each of the transects, including the two edge of water evaluations, so that the transect data would be more readily amenable to the data reduction format that was chosen for use in this particular survey.

In the case of most of the transect runs of the inventory, more than twelve points were actually assessed which provides a progressively better data base in relation to the reliability and validity of the project data manipulations. In only a very few instances were less than twelve transect points assessed on any given run. In general, the number of points that could be eventually evaluated along a transect line plus the number of individual station transects that could be completed during any of the trips were delimited by the time constraints that had to be imposed upon the field work.

Because of the inherent physical nature of the Poplar drainage streams, most of the study transects had to be run across the ponded or channelized segments of the rivers with the bulk of the macrophyte evaluations then obtained from these kinds of reaches. These ponded-channelized sections were generally quite wide and relatively deep with low current velocities and with typically fine but oftentimes quite variable substrates depending upon the particular station. The extreme depths that were observed in some of the pools proved to be a limiting factor to the project by precluding the quantitative examination of these deeper segments. That is, sections of the pools having depths much greater than four feet had to be avoided because of wading problems, and this provided one physical barrier to the macrophyte assessments of the project. Furthermore, a great deal of macrophyte data could not be collected from the narrower, shallower, swifter, and coarser riffle-type of stream segment primarily because of the overall absence of this kind of stream reach from the study area drainages; e.g., distinct riffles could not be found in the close vicinity of stations I, II, III, IV, and VII. However, obvious riffle reaches were located at stations V and VI on the East and main Poplar Rivers, and these segments were also examined to some extent to provide another basis of comparison for the project evaluations.

Since the results from the two riffle assessments were kept separate from the pool analyses, nine discrete sets of macrophyte data were ultimately secured from the investigation as follows: the ponded-channelized reaches at stations I, II, III, V, and VII; the ponded-channelized segments of stations V and VI (V-P and VI-P); and the riffle sections at the latter two stations (V-R and VI-R).

Transect Numbers and Spacing. As a second project guideline, and to insure the obtainment of an adequate project data base, a goal was established at the outset of the macrophyte investigation to establish at least twenty transects in total at each of the seven appraisal sites. This then required the running of six or more transects on each of the sampling trips. This goal was ultimately accomplished at all of the sites on a station basis, and with one exception (station VI), twenty or more transect runs were completed across the ponded segments of the rivers. However, only nine transects were initiated across each of the two riffle segments partly because of the limited expanses of these particular stream reaches.

On each of the visits to a site, fairly wide-spaced transects were run sequentially up or down the stream from the initial transect line. Distances between the transects varied somewhat depending upon the nature of the stream, but these inter-transect distances were most typically in the vicinity of 25 feet. On subsequent trips to the same collection site, the newer transects were established on a separate section of the river either a short distance upstream or downstream from the earlier work but directed away from the older transect crossings. In this manner, none of the transect lines from any of the trips overlapped into a segment of the stream that had been assessed through an earlier sampling effort. This avoidance of closely duplicate transects between site visits was found to be important because of stream disruption and plant uprooting as a result of the required wading activities. Such disruptions were most severe in reaches having mud or muck, stream bottom materials.

The field work that was completed at each of the appraisal sites during the three sampling trips ultimately produced somewhat evenly-spaced and macrophyte evaluated sets of transect lines across each of the stream stations that covered a well-defined and fairly lengthy stretch of the river. These exact same segments of the Poplar streams would then be reexamined in any sampling programs that might be undertaken in future years to provide additional macrophyte data for a time-related comparative study.

Macrophyte Definition--Kinds of Plants Studied

The most obvious types of plants that are given an aquatic macrophyte designation are the rooted vascular plants, either emergent or submersant, that are commonly characterized by their large and complex morphologies. In addition, the nonvascular aquatic mosses and algal charophytes are also typically considered to be aquatic macrophytes for these same general reasons. As a result, these three broad plant groupings provided the main focus of the macrophyte work. The vascular macrophytes that were examined consisted of the dicotyledonous and monocotyledonous flowering plants (angiosperms) along with the scouring-rushes (horsetails) or Equisetophyta.

In most instances, the non-charophycean algae of a water are not typically viewed as aquatic macrophytes, but in the case of the Poplar investigations, certain of the filamentous macroalgae that were present in the streams, having thalli readily visible to the unaided eye, were also included into the abundance and taxonomic evaluations of the study. These particular macroalgae can be divided into two broad classes: the floating forms that comprise the biotic "scums" on the water surfaces of the Poplar streams, and the totally submersed and non-epiphytic macroalgae that were found to be directly attached to the stream substrates, providing some degree of plant cover to these bottom materials. Transect applications identical to the ones that were directed to the "true" macrophytic plants were also utilized with reference to these two macroalgae groups. However, the project data refinements were conducted in such a way so that the abundance descriptions of the "true" macrophytes could be kept separate from the abundance estimates of the two macroalgae categories. In essence therefore, the macroalgae assessments can be best viewed as a subinvestigation of the overall macrophyte project.

Taxonomic Identifications

Field Collections and Laboratory Applications. In concert with the transect work that was conducted at the seven appraisal sites, 26 macroalgae samples involving 32 identifications and 112 macrophyte specimens were collected from the study area streams during the course of the three sampling trips for taxonomic assessment under laboratory conditions. These specimens were collected directly from the transect points for later reference, and the taxonomic evaluations that were performed in the laboratory then provided the means for recognizing and naming the "true" macrophytic plants that were encountered while making the various transect runs in the field. In the case of these "true" macrophytes, such field identifications and quantitative tabulations were made at the lowest taxonomic levels possible in light of certain restrictive features that will be described below. In addition, major restrictions were also encountered in terms of field recognizing the different macroalgae taxa.

Principal references that were used to taxonomically identify and systematically sort the plant specimens that were collected as a part of this study can be listed as follows: Booth (1950), Booth and Wright (1959), Fassett (1969), Hitchcock and Cronquist (1973), Smith (1950), Smith (1977), and Stafleu (1972).

Keying and Field Recognition Restrictions. A large number of the macrophyte specimens that were collected for the laboratory identifications could not be keyed to a specific epithet because of the lack of critical keying characteristics, primarily the absence of reproductive structures. But in the case of some of the plants, at least one specimen out of the many that were collected for a taxa was so endowed or was so morphologically distinct vegetatively that a species name could be eventually assigned to that particular type of plant. As a result, a somewhat detailed macrophyte species list could be compiled for the Poplar drainage, especially in conjunction with the information that is available from other investigations in the region (e.g., Baron, 1974). Nonetheless, a significant amount of taxonomic incompleteness still remained in the project per se as is illustrated by the following summary: The sedges (Carex), rushes (Juncus), horsetails (Equisetum), and charophytes (Chara and Nitella) could only be identified to genus, while the mosses (Bryopsida or Musci) and the grasses (Poaceae or Graminae) could only be identified to the class and familial levels respectively.

In the case of the sedges and grasses, no specimens that had flowering-fruiting structures were obtained from the study area streams partly because of the fact that these fairly abundant, edge of water taxa were almost always closely grazed at the transect locations. The sedges were recognized on the basis of the triangular stems that tend to characterize this paricular group of plants. In the case of the much more rare rushes, horsetails, and mosses, only a small assortment of relatively poor specimens were obtained from the Poplar waters, and they consistently lacked the essential keying features. In addition, no attempts were made to identify the charophytic genera to a species name because of the taxonomic subtleties of these algal forms. Such taxonomic restrictions in the laboratory were, in turn, ultimately reflected in the field work where the plant tabulations of the sedges, rushes, horsetails, mosses, and grasses had to be confined to the higher systematic levels noted above.

As a further field restriction, although the charophytes could be identified to genus in the confines of the laboratory, the field recognitions and tabulations of these plants were completed only at the familial level (Characeae) because of the general difficulty of efficiently separating these two charophytic groups while actually in the process of making a transect run. For the same basic reason, the bulrushes (Scirpus), the spike-rushes or spike-sedges (Eleocharis), and the bur-reeds (Sparganium) were also identified only to genus in the field even though the recognition of more than one species of each of these genera was possible in the laboratory for some of the collected specimens. Furthermore, essential keying traits were not present on all of the bulrush, spike-rush, and bur-reed individuals that were encountered at the many transect points, and this factor additionally curtailed the taxonomic applications of the project. However, thirteen of the aquatic macrophyte species in the study area streams were adequately distinct morphologically so that a specific handle could be attached to the plants at all of the transect sightings, and this includes the six species of Poplar drainage pondweeds (Potamogeton).

However, effective and efficient field identifications at the specific, generic, and familial taxonomic levels were not plausible for the filamentous macroalgae because of their small morphologies, and in this instance, field tabulations were recorded on a non-taxonomic basis and only with reference to their two broad modes of development, i.e., either as the floating algae or as the submerged bottom forms. Nevertheless, detailed taxa lists of algal genera and some algal species are now available for the Poplar drainage because of the accessory field collections and laboratory identification efforts of this project and primarily because of some earlier sampling programs in the region (e.g., Bahls, 1977; Cullimore, 1975).

PHYSICAL MEASUREMENTS

Stream Width, Depth, and Current Velocity

Two basic physical measurements were made at each of the points along the many primary transect lines in conjunction with recording the different kinds of macrophytic information at the same exact transect locations. The depth of the stream at a transect point was estimated to one-hundreths of a foot from the one-tenth foot rulings on the gaging rod that was used to define the vertical and secondary transect lines. At the same time, this rod was equipped with a standard pygmy gaging meter to provide a means for measuring the corresponding current velocities. A small piece of yellow tape was affixed to one of the meter cups so that the revolutions of the pygmy could be counted visually through an appropriate period of time as established by a stopwatch, and one revolution of the meter per second was equivalent to a current speed of one foot per second. The general clarity of the Poplar streams made such visual observations feasible, and this water clarity also enhanced the ease for gathering the vegetative data.

Such stream velocity measurements were generally made at about one-third of a foot below the water surface, although lesser depths had to be used at the shallower river locations. This one-third foot criterion was established by the nature of the aquatic vegetation at some of the transect points. In the case of the more luxurious submersant macrophyte growths extending fairly close to the water surface, velocity readings had to be taken very near to the surface of the stream in order to avoid an entangling of the meter among the aquatic plants. And for the purposes of consistency, this application was then followed at the other stream locations even though the plant growths in these cases would not be restrictive to deeper velocity evaluations. For the most part, the emergent vegetation of the streams was not so tightly packed so as to totally negate the use of the small pygmy meter for current measurements within these kinds of macrophyte stands.

The current velocity data (number of meter revolutions and time period) and stream depths that were obtained at the different secondary lines on a transect run were sequentially recorded on a field data sheet in association with the plant data that were collected from the same stream locations. As a final application, the width of the stream at a transect crossing was read directly from the primary transect line.

Stream Substrate

Along with completing the current velocity and stream depth evaluations at each of the transect points, the nature of the stream bottom materials at these locations was also assessed through the application of four basic substrate categories as follows: (1) the very fine-grained muds and mucks; (2) the somewhat coarser sands; (3) the very coarse-grained gravels; and (4) the large rocks and boulders. Furthermore, various two-way and a few three-way combinations of these substrate classifications were recognized in certain segments of the streams in addition to the single occurrence of any one of the four categories. For example, combinations of sand and muck, of muck and gravel, and of sand and gravel were commonly observed at some of the transect locations.

To quantify this substrate information, a number sequence was assigned to the four categories with the mucks given the lowest ranking of one, the sands a somewhat higher ranking of two, the gravels an intermediate ranking of four, and the rocks-boulders the highest ranking of eight. In the case of the mixed substrates at a stream location, a single mean value was calculated from the related categories so that the muck-sand combination had a substrate reference number of 1.5, the muck-gravel combination a number of 2.5, the sand-gravel combination a number of 3.0, the gravel-boulder combination a number of 6.0, and so on. As a result of these assessments, qualitative descriptions of the stream bottom materials are available for each of the transect points at a station as recorded on the field data sheets, and quantitative expressions of these materials have also been established in the form of the substrate reference numbers.

WATER QUALITY EVALUATIONS

Data Availability

An extensive water quality sampling program was not included into this macrophyte survey because of the ongoing and fairly extensive monitoring activities of this kind that are being conducted by the United States Geological Survey (USGS) in the Poplar region. A wide variety of parameters including the common ions and pH, total dissolved solids, nutrients, dissolved oxygen, turbidity-suspended sediment, specific conductance, certain metals, and temperature, as well as flow, are being and have been monitored on a regular basis since June of 1975 at eight Montana stations in the drainage (USGS, 1975-1979). Although the USGS sampling locations do not exactly match the macrophyte appraisal sites, at least one of the USGS stations is in close proximity to any one of the macrophyte sites so that this agency's data should be generally applicable to any extensive water quality factor analyses that might be directed to the macrophyte information. In addition, some data for a few other stream stations are also available from this agency, and water quality information from a variety of locations in this same drainage has been collected by other governmental and private entities, both in Montana and in Saskatchewan. Most of this non-USGS data and all of the earlier USGS collections for the Poplar basin have been summarized by Klarich (1978).

Parameters and Rationale

In spite of the USGS sampling efforts, a small and select set of water quality parameters was monitored during the course of this project to help further define the water quality components of the macrophyte's environment. A limited evaluation of this kind was thought to be important to the study since the USGS did not directly sample the water at all seven of the macrophyte appraisal sites. Parameters that were assessed in this sampling program include pH, specific conductance, turbidity, dissolved oxygen, temperature, and water transmittances at light wavelengths of 450 and 650 millimicrons.

Specific conductance was monitored to provide further information on the salinity levels of the streams, and pH was evaluated as a means of obtaining some general insights into the primary production characteristics of the Poplar waters. That is, highly productive aquatic systems often have relatively high daytime pH values over 9.00 standard units because of the pH elevations resulting from an extensive photosynthetic use of the water's carbon dioxide and bicarbonate constituents. In addition, daytime dissolved oxygen concentrations are often supersaturated in productive systems because of the rapid photosynthetic release of oxygen from water photolysis. Less productive systems, in contrast, have lower photosynthetic activities and lower and more "normal" oxygen levels near atmospheric saturation; they also have lower carbon dioxide and bicarbonate utilization rates that typically result in more moderate pH values in the range of 7.5 to 8.5 units.

As a further consideration, extremely high and low pH's are generally observed to be limiting to most kinds of aquatic organisms, as are relatively low dissolved oxygen levels, and these features provide additional reasons for determining the pH and dissolved oxygen values of the Poplar basin rivers. In the latter instance, however, nighttime dissolved oxygen concentrations would have been more meaningful but this type of information was not collected during the project. In the same vein, salinity was assessed because of the adverse effects this water quality parameter can have on freshwater organisms when at relatively high levels.

Stream temperatures were monitored because of the overall importance of this variable, and water turbidity was evaluated because it provides some information on the streams' suspended sediment levels. This latter parameter can also have adverse effects on submerged plants by smothering when at extremely high concentrations, but more significantly, turbidity affords an indirect measure of water transparency and the degree of light penetration to the streams' bottom materials. A high turbidity would be reflective of a low light transmittance, and this feature can readily delimit macrophyte growth and development through an indadequate light availability for photosynthesis in the vicinity of the submerged macrophyte beds. This was viewed as potentially important for the Poplar River system in relation to the deep nature of some of the pools.

Because of the general importance of light as a limiting factor to submerged aquatic plants (Davis and Brinson, 1980), light transmittance at the 450 and 650 millimicron wavelengths was determined for the Poplar water samples in order to obtain a more quantitative expression on the degree of light penetration in the study area streams. These two wavelengths were chosen for this application because they closely correspond to the "red and blue" peaks of the chlorophyll absorption spectrum, and because they also generally correspond to the two peaks of the photosynthetic action spectra that are seen in many kinds of plants (Salisbury and Ross, 1978). With this assessment of light transmittance plus an analysis of the other five water quality parameters, a great deal of information can be obtained that describes the biologically important factors in the water quality portion of the lotic environment.

Sample Collection and Analysis

With the exception of dissolved oxygen, grab samples were collected from each of the stream stations on each of the three sampling trips by using plastic liter bottles, and water analyses were conducted as soon after collection as possible in the Billings, Montana branch laboratory of the State Water Quality Bureau, Montana Department of Health and Environmental Sciences. The water was collected while completing the series of transect runs at a site. Stream temperatures were measured on site with a calibrated centigrade (C) mercury thermometer, but in contrast to the water samples, a surface temperature reading was obtained at some point during each of the transect crossings, providing six or more temperature values for each of the stations, sampling dates, and transect time periods.

A calibrated Orion Research Specific Ion Meter, Model 407A, was used to determine the pH value of a water sample, and a calibrated, temperature correctable Lab-Line Instruments Lectro Mho-Meter, Model MC-1 Mark IV, was used to measure the water's electrical conductance in micromhos at 25C. Turbidity levels as nephelometric turbidity units (NTU) were obtained with a Hach Chemical Company Model 2100A Turbidimeter, and a Bausch and Lomb Spectronic 70 spectrophotometer was used to measure the percent light transmittance values of the water samples at the two selected wavelengths.

Water samples for the dissolved oxygen determinations were collected on the last two trips to the Poplar study area using standard glass BOD bottles. The samples were analyzed for their dissolved oxygen concentrations by utilizing the azide modification of the iodometric or Winkler method that is described in Standard Methods (American Public Health Association, *et al*, 1975). Following the rationale and procedures outlined by Karp and Klarich (1978), the oxygen samples were first fixed in the field by adding manganese sulfate and alkaline-iodide-azide to form a stable, oxygen-binding floc, and the final acidification and starch endpoint-phenylarsine oxide titration steps were performed in the Billings laboratory as soon after arrival as possible in order to avoid a prolonged storage period that could have biased the oxygen data. In addition to a determination of oxygen concentrations *per se* in milligrams per liter, the percent saturation levels of this parameter were also established by using the barometric pressure-altitudinal and temperature features of the Poplar sampling sites in conjunction with a dissolved oxygen saturation table that is available for these three variables from the Hach Chemical Company (1973).

PROJECT DATA MANIPULATIONS

RAW DATA REFINEMENTS--PRINCIPAL PLANT PARAMETERS

Preliminary Considerations

The raw data of the study excluding the water quality analyses that were secured from the field included several items as follows: (1) listings of the transect point distances across each of the station's transect lines from the initial edge of water reading at zero feet to the last transect reading on the opposite bank that described the width of the stream; (2) a listing of the plant taxa in the vicinity of each of the transect locations on a primary line, or the nonoccurrence of plants at the appropriate transect locations (i.e., a bare substrate notation); (3) each of the taxon's low, medium, or high abundance characteristics at any of the points; an abbreviated note regarding the (4) emergent-submersant and the (5) vegetative-reproductive conditions of each of the plants; and (6) the physical measurements that were made at each of the transect points as outlined earlier.

The initial step in assessing the above described plant information involved a refining of the raw data into percent occurrence variables for each of the taxa and for the community as a whole, and two such expressions were developed for the project: a "true" percent occurrence or "true" percent canopy cover that ignored the three abundance categories, plus a "weighted" percent occurrence or "weighted" percent canopy cover in which the abundance estimates were included into the calculations.

True Percent Canopy Cover

The true canopy cover value of a taxon for a set of transect locations, expressed as a percent, is based only on the presence or absence of taxon individuals at the separate secondary lines, and it is calculated as the number of taxon occurrences among the transect points divided by the total number of points in the data set. True taxon canopy cover can therefore vary from zero percent where no taxon tabulations were made to a value of 100% where individuals of a taxon were observed in the vicinity of every one of the secondary lines. The percent occurrence of bare stream substrate can then be calculated in a similar fashion.

As a further application, a true total canopy cover value can be established for the plant community at a set of transect points by simply summing the true canopy cover values of the different taxa that were recorded for the set. True total canopy cover can thereby range from zero percent in the case where no plant observations were made to values that are greater than 100% in the case where more than one plant taxon was tabulated for a large number of the transect locations. For example, if an average of one and one-half taxa were tabulated for each of the secondary lines in a data set, then the total true canopy cover of the aquatic plants would be equal to 150%. As a maximum and extreme value, total canopy cover could conceivably be equal to 100% times the number of taxa identified at a station if all the taxa were tabulated at each of the transect points.

Another parametric expression along these lines, termed true total vegetative canopy cover, can also be determined where the numbers of individual taxa occurring at a transect point are ignored in favor of only noting the presence or absence of aquatic vegetation *per se*. This variable can then range from zero percent with no vegetation to an extreme upper limit of 100%, and total vegetative canopy cover can be calculated for a data set by simply subtracting the percent occurrence of bare substrate from 100%. In view of this discussion, true taxon canopy cover and true total canopy cover along with total vegetative canopy cover and the percent occurrence of bare stream substrate represent four of the major community parameters that were calculated for the project assessments. Two other kinds of basic study variables are outlined below.

Weighted Percent Canopy Cover

Abundance Class Quantifications. The true taxon canopy cover and true total canopy cover parameters are the typical derivations that are developed from plant community evaluations that use the transect methodology. The "weighted" expression, therefore, represents a modification of this standard approach by also utilizing the three macrophyte abundance-biomass classes that were described previously. For this study, these categories were quantified to provide the option for performing various mathematical manipulations, and the "high" category was thereby assigned a value of ten, the "medium" category a value of five, and the "low" category a value of one. The non-occurrence of a taxon at a secondary line was given a value of zero.

This quantification of the abundance classes basically assumes that a taxon was about ten-times more abundant at the transect points having a high rating than it was at stream locations given a low rating, and approximately two-times more abundant in the high assignation over the medium case; and it was roughly five-times more abundant at the transect points with a medium ranking in relation to the secondary lines that were relegated to the low category. This rating system was developed on the basis of numerous qualitative observations that were made in the field, and it appears to afford a fairly representative approximation of the biomass characteristics of the many study area taxa that were observed through the different stream reaches of the drainage. For the most part, these three abundance classes were designed to be adequately broad-based and simple so that the categorical biomass separations of a taxa could be relatively straightforward when making a transect run.

Taxa Derivations. Using the numerical values of the abundance categories, the weighted percent canopy cover of taxon can be determined by simply adding the categorical ratings that it received at the different transect points of a data set and dividing by ten-times the total number of transect points in that set (followed by the percentage adjustment). In this way, weighted taxon canopy cover, like true taxon canopy cover, can range from zero percent with the complete absence of a particular macrophyte from the data set to 100% where the taxon was highly abundant at all of the transect locations.

Similar to the true expression, weighted taxon canopy cover will drop below 100% if a taxon is absent from some of the secondary lines, but it will also drop below 100% when the taxon has low or medium abundance rankings at one or more of the stream locations. This latter decline in weighted taxon canopy cover will occur even when the macrophyte happens to be present at all of the transect points, and this is not the case for its sister variable. As a result of this fact, the weighted calculations have the potential for being more sensitive than true taxon canopy cover in detecting taxon abundance differences between separate aquatic plant communities. That is, a taxon can demonstrate similar areal densities in two different stream reaches while having greater overall biomass levels in one segment over the other, but the true canopy cover evaluation, by its design, would not be able to identify these kinds of inter-segment differences. The weighted evaluation, however, would be able to pinpoint such a variation if the biomass discrepancies between the stream comparatives are adequately pronounced so as to be recognized via the three abundance categories. This then provides the basic reason for including the weighted assessments into the project data manipulations.

The true and weighted taxon canopy cover numbers of a particular macrophyte in a data set are equal in those instances where taxon was found in the high abundance category at all of the transect points at which it was found, and this relationship is independent of the density characteristics of the plant. In contrast, true canopy cover is ten-times greater than weighted canopy cover in those cases where a taxon was found to have a low abundance ranking at all of the taxon observations, and this relationship is also independent of plant densities. These features then prescribe the mathematical limits to the differences that can be observed between the two project canopy cover variables with the true:weighted taxon canopy cover ratios ranging between values of one and ten. True:weighted ratios that approach one are suggestive of fairly high taxon biomass levels at some or all of transect points of a data set, while ratios that are closer to ten point to the occurrence lower abundance characteristics.

Community Derivations. As another manipulation of the project data, the weighted total canopy cover of a plant community in a data set can be determined by simply adding the individual weighted taxon canopy cover numbers of the different macrophytes that might be encountered in a set of transect points. This weighted total canopy cover variable, like the case for true total canopy cover, can range from zero percent with the complete absence of aquatic vegetation to values in excess of 100% in situations where most of the transect points are covered by taxa having generally high biomass levels. But as a general rule, the weighted canopy cover will be less than 100% if the average categorical abundance ranking of the taxa in a data set is less than a separate value that is equal to ten divided by the average number of taxa per transect point. For example, if a plant community demonstrates an average categorical biomass ranking of 3.2 for the different plants encountered plus an average of 1.7 taxa per transect location, then the weighted total canopy cover of the community would only be equal to 54.4%. In essence, the average biomass rating of the plants has to be equal to the average number of taxa per transect point, with the latter equivalent to 0.01 times true total canopy cover, in order for the weighted total canopy cover number to be equal to 100% after the percentage correction. Therefore, weighted total canopy cover values that are less than 100% appear to be most typical in aquatic plant communities because of the general uncommonness of this latter condition.

In the case of a complete absence of aquatic plants from a transect point, the corresponding recognition of bare substrate was assigned a value of ten in the weighted evaluations so that the percent occurrence of non-vegetated stream bottom materials in the data set would have the same magnitude in both the weighted and the true canopy cover manipulations. Total vegetative canopy cover, thereby, also has identical percentages in both of these derivations relative to the definition for this parameter that was presented above.

Total Canopy Cover Ratios

Use in Community Assessments. On top of the weighted and total canopy cover parameters that were defined previously, three other mathematical operations were directed to the project data in order to illustrate certain aspects of the macrophyte communities in the Poplar drainage streams.

One of these manipulations involved the calculation of a true:weighted total canopy cover ratio for the different data sets. This ratio has the same density independence characteristics as the true:weighted taxon canopy cover ratio that was mentioned earlier, and the true:weighted total canopy cover expression provides a means of describing the overall abundance features of plant vegetation at the different Poplar appraisal sites. That is, true:weighted total canopy cover ratios approaching one are suggestive of relatively high abundance levels in the stream sections having plants, while ratios approaching ten point to the occurrence of a much lower abundance profile in the macrophytic vegetation. Furthermore when the true:weighted total canopy cover ratio is used in conjunction with the density dependent total vegetative canopy cover expression, a general description of the density-biomass features of a plant community can be obtained. Four basic comparisons along these lines are possible as described below.

On the one hand, a low true:weighted total canopy cover ratio in association with a large total vegetative canopy cover percentage (option I) is suggestive of a highly dense and tightly packed plant community that has a high biomass level and a distinct vertical appearance. This description would most closely coincide with the occurrence of pronounced macrophyte weed beds that are found in some aquatic systems. At the other extreme (option II), a high true:weighted canopy cover ratio along with a low total vegetative canopy cover value is indicative of the presence of a small number of widely scattered, individual plants that impart a relatively sparse vegetational overlay to a lotic or lentic substrate.

As a third option, if both the total vegetative canopy cover and the true:weighted total canopy cover values are relatively high, the plants of the community would be much less scattered than the case for option II while still lacking a pronounced verticality so that the aquatic vegetation in these instances affords a carpet-like quality over the bottom materials. Both options II and III paint distinctively different vegetational pictures from the thick, deep, and luxurious plant beds that are described by option I.

In the final comparison (option IV), low true:weighted total canopy cover ratios plus low total vegetative canopy cover percentages indicate the occurrence of widely separated but distinct vegetational groupings that have high biomass levels and distinct vertical features. This description is in accord with the observation of scattered macrophyte "mounds" that are found in some lotic waters where plant development is dependent upon an initial entrapment of fine substrate materials at a small number of suitable stream locales. This silt entrapment then leads to the preliminary establishment of a few aquatic plants at these stream locations, and a successional process then follows that includes further silt deposition because of the pioneer organisms and additional plant establishment because of the accrued silt. The high biomass macrophyte mounds are thereby gradually built in this fashion at various spots throughout the stream reach. In this case, high plant biomass values are recorded when encountering one of the mounds, but relatively low overall densities are eventually tabulated along the transect lines because of the dispersed nature of these plant aggregations.

Ecological Relationships. The type of plant community that is elucidated by the latter description would be most typically observed in stream reaches having fairly pronounced current velocities that are potentially delimiting while having a general suitability of the other environmental factors for a luxuriant macrophyte growth. Option I, in turn, would be most likely found in lentic systems and in the ponded reaches of streams where all of the environmental factors are again amenable for extensive plant development, and this would include an adequately low current speed. Option III, however, is suggestive of some environmental stress that retards excessive macrophyte growth in standing and slowly moving waters, while option II might be found in all types of waters where some environmental factors, including rapid water velocities, are markedly restrictive to aquatic plant establishment and their subsequent proliferation. The extreme case for option II is the total absence of macrophytic vegetation.

Of course, plant communities with characteristics that are intermediate to the four options described above can be found in various aquatic systems under differing environmental conditions. Nevertheless, these four basic descriptions are still useful for generally delineating the type of aquatic plant organization that might be found in any particular situation.

Other Expressions

One of the two remaining accessory operations that were directed to the project data involved a calculation of the average number of taxa that were recorded for each of the vegetated secondary lines of a data set. This variable is similar to true total canopy cover except for the percentage adjustment and the fact that true total canopy cover includes the occurrence of bare substrates whereas the recognition of nonvegetated transect points was excluded from this other manipulation. The true total canopy cover expression, therefore, basically describes an average taxa frequency along the transect crossings of a station, while this accessory ratio denotes the average number of taxa that would be found at a typical transect location having aquatic plants. Since only one count of a taxon was registered at any one of the secondary lines, this accessory ratio was calculated by totaling all of the plant observations that were made at an appraisal site and dividing by the total number of transect points that happened to be covered by macrophytic vegetation.

The final accessory expression describes the average categorical biomass ranking that was obtained for the various macrophytic tabulations at each of the sampling stations. Such manipulations were performed on a community basis by summing the categorical rankings that were given to all of the individual plant sightings and dividing by the total number of plant observations that were made through all of the taxa. This was also done on a taxa basis by adding the biomass rankings that were given to the plant sightings of any given taxon and dividing by the total number of observations that were made for that same kind of plant. These particular ratios are not directly equivalent to the weighted canopy cover manipulations because of the exclusion of the bare substrate encounters from their calculation and because of the elimination of the ten-times factor which is an integral part of the weighted derivation.

PLANT DATA CLASSIFICATIONS

Blocking by Growth Form

The true and weighted total canopy cover values of the project describe the abundance-density characteristics of the macrophyte communities that were examined at the different sampling sites, and the true and weighted taxon canopy cover values describe the abundance-density attributes of the individual plant taxa that happened to comprise any one of these macrophyte assemblages. In addition to these basic applications, the total canopy cover data were also classified or blocked, i.e., subdivided, in various ways so that subsets of canopy cover numbers were obtained to illustrate the nature of certain components of a station's aquatic vegetation.

One type of blocking was directed to the separation of both true and weighted total canopy cover on the basis of the emergent and submersant macrophyte groupings in the streams. This was done by first separately summing the taxon canopy cover percentages of those taxa at a station that were always either totally emergent or submersant in form. In the case of an amphibious habit, a blocking of this kind had to be initially performed at the taxa level in order to differentiate between the contradictory emergent and submersant vegetative life-styles of these kinds of aquatic plants. The individual taxon canopy covers that were obtained for the emergent and submersant forms of an amphibious plant were then included into one of the corresponding total canopy cover additions.

Attention was focused upon the emergent and submersant vegetational aspects of the Poplar drainage because one of the potential impacts projected from the Coronach impoundment invokes an ultimate increase in the proportion of emergent vegetation in the East Poplar River. Such an alteration could lead to a general deterioration in waterfowl habitat, and baseline data of this kind will be important in future comparative work in conjunction with the aerial photographic applications that were noted earlier (DeSimone, 1980).

Although the occurrence of floating-leaved plants was recorded in the field, a separate delineation of these observations from the emergent-submersant classes was not deemed worthwhile when making the data summaries because of the low frequency and general non-dominance of this type of morphology. Furthermore, most of the plants that did exhibit floating leaves had a much more distinct emergent or submersant component that widely overshadowed the floating plant parts on a biomass basis. Therefore, the floating-leaved tabulations were combined with those of the submersant group. However, canopy cover values of this kind can be eventually calculated for the project if the need for this type of data should happen to arise for future comparative applications.

Blocking by Reproductive Status and Sampling Date

In contrast to the emergent-submersant classifications, the taxon canopy cover values that were calculated for the main data summaries of the stations do not discriminate between the reproductive and nonreproductive aspects of the Poplar macrophytes. However, the individual plants of a taxon that happened to have flowering or fruiting structures were recorded as separate entities from the vegetative forms when making a transect run, and as a result, accessory canopy cover percentages were determined for both the vegetative and the reproductive stages of the appropriate taxa. But this particular feature of the stream communities was not evaluated as a part of the principal assessments of the project, and it will be considered in separate discussions.

In the case of most of the mathematical manipulations of the project, the results from the three field assessment trips were combined to form an enlarged data base for the various data refinements. However, true and weighted canopy cover values were separately calculated for each of the site visits in the study area so that separate sets of figures would be available for each of the three sampling dates at a station. This type of blocking was applied to the inventory primarily for statistical purposes in the sense of providing a means for judging the consistency, variability, and general reliability of the macrophyte assessment program through a comparison of these three sets of numbers. However, the possibility of natural seasonal changes in the plant communities through the late July to mid-September sampling period was also considered as a potential causal factor for any inter-trip differences that might have been observed in the macrophyte data. These aspects will be more specifically addressed in a later section of this report.

Transverse Blocking by Stream Sector

Another type of data separation that was applied to the project involved a blocking on the basis of several stream sectors that were delineated by a series of interval distances across the different primary transect lines of a station. These sectors were defined as the two edge of water locations plus ten consecutive transect subsections with each of these equalling ten percent of the total transect width. Except for the edge of water sectors, the remaining non-edge stream segments provided an aeral perspective to these analyses as a result of combining the corresponding sectors from the different station transect lines. This latter combination afforded an up and downstream linear aspect to the sector areas, while the width aspect of the area was defined by a segmental distance along the length of the transect crossings. Since no reason arose for distinguishing between one side of a river over the other, the two mirror-image sectors from each side of the stream were combined to ultimately produce six discrete stream sectors for each of the appraisal sites. In the case of stations V and VI, sectors of this kind were separately established for the riffle and ponded reaches.

Excluding the edge of water sector, each of the five instream segments consisted of two, ten percent, mirror-image pieces from each of the many transect lines across the stream. Starting with the middle of stream segment, these sectors can be more specifically defined on a percentage basis as follows: middle--40.00% to 60.00%; near middle--30.00% to 39.99% and 60.01% to 70.00%; intermediate middle--20.00% to 29.99% and 70.01% to 80.00%; intermediate edge--10.00% to 19.99% and 80.01% to 90.00%; and near edge--0.1% to 9.99% and 90.01% to 99.99%. The edge of water sector then would have percentages of zero and 100%. The points on a station's transect lines that happened to fall within any one of these six sectors were ultimately combined to form a unique data set, and the related biological observations were pooled prior to performing the various mathematical manipulations.

Thus, descrete sets of refined project data were developed for each of the stream sectors at a station as well as for the entire community.

Longitudinal Frequency

The sector evaluations described above provide an across-the-stream or transverse structural profile of the vegetative growth form, abundance-density, and taxonomic characteristics of the plant communities inhabiting the stream reaches that were assessed during the inventory. To allow for another viewpoint, percent transect frequency values were calculated for each of the taxon at a station as a means of obtaining some insight into the upstream-downstream or longitudinal distributional features of the taxa within a study segment. This variable was defined as the number of transect lines on which the plant was found divided by the total number of transect crossings utilized at a sampling location. A low transect frequency percentage, therefore, would point to a patchy and discontinuous type of taxon distribution along the stream reach of an appraisal site, while a high frequency would be indicative of a more consistent and continuous form of distribution along the length of a stream. Further interpretations along these lines can be directed to a taxon if its all-station and stream sector canopy cover percentages are also considered in conjunction and its transect frequency values.

PHYSICAL DATA CLASSIFICATIONS

Like the case for the biological observations, the physical measurements that were obtained from the transect points of a station were also combined on the basis of the six stream sectors, and mean current velocities, depths, and substrate reference numbers were calculated for each of these stream segments. Furthermore, overall averages of these physical variables were also established on a station basis.

To further define the physical environment of the Poplar streams, four additional descriptive expressions were developed from the pooled physical data of each of the stream sectors, and as one of the manipulations, the percentage of transect points exhibiting a zero current velocity was determined. Secondly, a "typical" maximum depth was derived for each sector by first taking the two greatest depth values that were measured for that sector on each of the field trips and by the massaging of these numbers to provide a six-way average maximum depth value for any particular station segment. And finally, the percent occurrence of fine-grained substrates (mucks and sands) at the transect points of a sector was determined along with the percentage of coarser stream bottom materials at that location, including the gravels, rocks, and boulders. Zero current velocity frequencies and the coarse and fine-grained substrate occurrences were also calculated on a station basis, and the "typical" maximum depth value of each of the sampling sites as a whole was determined as an average of this variable across the six stream sectors.

The availability of the mean current velocity values, mean depth values, and the mean substrate reference numbers for the various stream sectors in association with the availability of different kinds of refined biological data for these same segments afforded the option for conducting a preliminary and precursory assessment of the potential influence of these physical parameters on the distribution and abundance features of the Poplar drainage aquatic plants. The details and results of this particular evaluation will be described later.

AQUATIC PLANTS ENCOUNTERED--QUALITATIVE SYNOPSIS

TAXA LIST

Tabular Roster

Table 2 presents a systematically organized listing of the emergent and submersant aquatic macrophytes that have been identified by different researchers working in the Poplar River drainage of northeastern Montana and south-central Saskatchewan. As one deviation, the systematic arrangement of this table excludes the order level since this category did not act to additionally distinguish the macrophytes from one another to any significant degree. The non-order systematic levels and taxa that were identified in the laboratory phase of this recent inventory are specifically noted in Table 2 as are the unique taxa not collected in this survey but observed in other studies in the Poplar basin (Baron, 1974; Cullimore, 1978 and 1976; Saskmont Engineering Company, 1978; Tennant and Loch, 1979).

In addition to the numerous kinds of embryophytic higher plants or "true" macrophytes that were observed in the region, the taxa listed in Table 2 also include the algal charophytes of the drainage, which are typically viewed as macrophytes, along with the various floating and bottom macroalgae that were classified as macrophytes for the purposes of this particular study. When all of the surveys are combined, 43 discrete taxa of aquatic macrophytes in accord with these guidelines were collected from the Poplar waters with the word "discrete" referring to those taxonomic identifications that were taken to the lowest systematic levels possible within the confines of any of the individual projects. These 43 discrete taxa, in turn, are representative of two plant subkingdoms, six divisions, eight classes, 25 families, 33 genera, 33 species, and three varieties.

Systematic Details

One of the two subkingdoms noted in Table 2 delineates the thallophytes which include the algal forms, and eight descrete taxa of macrophytic thallophytes were identified as genera along with one species recognition. These nine organisms account for 50% of the plant divisions and classes and for about 25% of the total family designations that were identified during the study, and each of these families contained only one or two of the algal genera. Seven of these plants can be classified as macroalgae, while the other two fall into the charophytic group. The thallophytes, therefore, made a major contribution to the floral diversity of the Poplar streams in terms of the higher, division and class systematic layers of the plant kingdom while making a much less significant contribution to the flora of the waters in terms of the systematically more refined generic and specific levels.

The other subkingdom of aquatic macrophytes in the Poplar drainage consists of the various embryophytes which account for 34 of the discrete

Table 2. Taxa list, partial systematics, and common names of aquatic macrophytes collected from streams in the Poplar River basin of Montana and Saskatchewan (the first of two pages).

SK. THALLOBIONTA: non-embryophytes or thallophytes
D. CYANOPHYTA: blue-green algae
C. CYANOPHYCEAE (MYXOPHYCEAE)
F. Nostocaceae
    Anabaena variabilis Kutz*°
D. CHLOROPHYTA: grass-green algae
C. CHLOROPHYCEAE: non-charophytic green algae
F. Cladophoraceae--river "mosses"
    Cladophora Kutzing*
    Rhizoclonium Kutzing*
F. Oedogoniaceae
    Oedogonium Link*°
F. Zygnemataceae--pond "scums"
    Mougeotia Wittrock*
    Spirogyra Link*
C. CHAROPHYCEAE: charophytic green algae
F. Characeae--stoneworts
    Chara Valliant*--muskgrasses
    Nitella Agardh*--bright stoneworts
D. CHRYSOPHYTA: golden or "pill-box" algae
C. XANTHOPHYCEAE: yellow-green algae
F. Tribonemataceae
    Tribonema Derbes and Salier*

SK. EMBRYOBIONTA: embryophytes
D. BRYOPHYTA: nonvascular embryophytes
C. BRYOPHYCEAE (MUSCI)*°: mosses
D. EQUISETOPHYTA (SPHENOPHYTA): nonflowering tracheophytes or vascular embryophytes
C. EQUISETOPHYCEAE
F. Equisetaceae--Horsetail Family
    Equisetum L. sp.*--scouring-rushes
    Equisetum arvense L.#--common scouring-rush
D. MAGNOLIOPHYTA (PTEROPHYTA): flower-bearing tracheophytes or vascular embryophytes
C. LILIOPHYCEAE (ANGIOSPERMAE-MONOCOTYLEDONAE): monocotyledons
F. Alismataceae--Water-plantain or Arrowhead Family
    Sagittaria cuneata Sheld.*--arumleaf arrowhead or wapato
F. Cyperaceae--Sedge Family
    Carex L. sp.*--true sedges
    Carex atherodes Spreng.*--awned sedge
    Eleocharis acicularis (L.) R. and S.*--needle spike-rush
    Eleocharis palustris (L.) R. and S.*--creeping spike-rush
    Scirpus acutus Muhl.*--hardstem bulrush
    Scirpus americanus Pers.*--American or three-square bulrush
    Scirpus validus Vahl*--softstem or great bulrush
F. Juncaceae--Rush Family
    Juncus L. sp.*--rushes
    Juncus balticus Willd. var. *montanus* Engelm.#--Montana Baltic rush

Table 2. Continued (the second of two pages).

C. LILIOPHYCEAE (D. MAGNOLIOPHYTA)--continued
F. Poaceae (Graminae)*--Grass Family
Beckmannia syzigachne (Steud.) Fern.#--American sloughgrass
Glyceria grandis Wats.#--American or reed mannagrass
Spartina pectinata Link*°--prairie cordgrass
F. Pontederiaceae--Pickerel-weed Family
Heteranthera dubia (Jacq.) MacMill.*--water star-grass
F. Potamogetonaceae (Najadaceae)--Pondweed Family
Potamogeton filiformis Pers.*--slender-leaved pondweed
Potamogeton foliosus RaF.*--close-leaved pondweed
Potamogeton pectinatus L.*--fennel-leaved pondweed
Potamogeton richardsonii (Bennett) Rydb.*--Richardson's pondweed
Potamogeton robbinsii Oakes*--Robbin's pondweed
Potamogeton vaginatus Turcz.*°--sheathing pondweed
F. Sparganiaceae--Bur-reed Family
Sparganium angustifolium Michx.*°--narrowleaf or floating bur-reed
Sparganium eurycarpum Engelm.*--broadfruited bur-reed
F. Typhaceae--Cat-tail Family
Typha latifolia L.*--common cat-tail
F. Zanichelliaceae--Horned Pondweed Family
Zanichella palustris L.*--horned pondweed
C. MAGNOLIOPHYCEAE (ANGIOSPERMAE-DICOTYLEDONAE): dicotyledons
F. Apiaceae (Umbelliferae)--Parsley Family
Sium suave Walt.#--hemlock water parsley
F. Asteraceae (Compositae)*°--Composite or Aster-Sunflower Family
Bidens ceruna L.#--nodding beggar-tick or sticktight
F. Haloragaceae--Water-milfoil Family
Myriophyllum spicatum L. var. *exalbescens* (Fern.) Jeps.*--common spiked water-milfoil
F. Hippuridaceae--Mare's-tail Family
Hippuris vulgaris L.*--common mare's tail
F. Lamiaceae (Labiatae)--Mint Family
Lycopus americanus Muhl.#--cut-leaved water horehound
Mentha arvensis L.*--corn or field mint
F. Lentibulariaceae--insectivorous Bladderwort Family
Utricularia vulgaris L. var. *americana* Gray#--American common or greater bladderwort
F. Polygonaceae--Buckwheat or Knotweed Family
Polygonum L. sp.@--knotweeds or smartweeds
Polygonum amphibium L. (*Polygonum natans*)#--water smartweed
F. Ranunculaceae--Buttercup Family
Ranunculus sceleratus L.#--celery-leaved or blister buttercup
F. Rosaceae--Rose Family
Potentilla L. sp.@--cinquefoils

*Taxa and lowest systematic level typically identified in the laboratory keying efforts of this intensive survey; °denotes the collection of only one plant specimen. #Taxa and systematic levels not recognized in this inventory but included in the Canadian listings. @Taxa not collected in this inventory but observed in other Montana studies. SK-subkingdom, D--division (phyla), C--class, and F--family; var. points to a varietal name.

taxa separated into three divisions, four classes, and nineteen families with 24 genera, 32 species, and three varieties. One of the embryophytic taxa was represented by a nonvascular-nonflowering moss that could only be identified to class, while another was represented by the vascular but non-flowering scouring-rush genus Equisetum. These two plants alone provided two of the systematic divisions and classes that were recognized for the region, but they were representative of only 5% of the discrete taxa. Thus the Bryophyceae and Equisetophyceae were found to be floristically unimportant constituents of the Poplar vegetation, although they did afford 25% and 33% of the higher systematic recognitions.

The other plant division collected from the Poplar drainage contains the embryophytic flowering-vascular forms that are split into two large classes (monocots and dicots), and these particular macrophytes impart the greatest degree of floristic richness to the upper Poplar drainage at the lower systematic layers. The monocots provided 22 discrete taxa in nine families, thirteen genera, 22 species, and one variety, while the dicots provided ten discrete taxa in nine families, ten genera, nine species, and two varieties. Of the flowering plant families, the Cyperaceae revealed the greatest diversity with three genera and six species followed by the pondweeds with six species in one genus and the grasses with three aquatic genera and species. All of these species-rich families are monocotyledonous in character. In contrast, 11% of the dicot families (11% monocot) had two representatives while 89% (56% monocot) had only one type of plant. As a result, the monocots were observed to be more floristically diverse in the Poplar streams than their dicotyledonous counterparts.

Three of the 43 discrete taxa were identified as varieties (all angiosperms), 29 as species (mostly angiosperms), nine as genera (mostly algae), and one at the class level (the bryophyte). This suggests that a high degree of taxonomic resolution was ultimately made available for the aquatic macrophytes of the Poplar basin as a result of the various inventory projects. In light of the wide variety and number of plants at the different systematic levels, the aquatic macrophyte communities of the upper Poplar system do provide a fair amount of floral diversity and richness to the streams.

Individual Study Contributions

Canadian Comparisons. In the case of this recent inventory, 33 macrophytic taxa were recognized in the study area streams at the levels of taxonomic resolution that were inherent to the subject. This includes the nine algal genera, the one bryophyte class, a single genus of scouring-rushes, eighteen monocots, and four dicots. However, some of these listings are not representative of discrete taxa for the Poplar drainage because identifications had been taken to lower systematic categories in other basin surveys (Table 2). For example, of the 33 algal and higher plant taxa observed in this study, 21 were also spotted in the Saskatchewan portion of the basin as a result of the baseline studies that were conducted in the province in conjunction with the power generation development near Coronach, and in five of these cases (i.e., Equisetum, Carex, Juncus, Poacea, and Asteraceae), the Canadian surveys (Baron, 1974; Cullimore, 1976; Saskmont Engineering Company, 1978) were able to produce generic and/or specific names which could not be keyed in the post-1980's work (Table 2).

Collecting efforts in the Saskatchewan portion of the study region also provided several unique contributions to the basin's aquatic macrophyte flora in the sense that these taxa were not collected in this later project. Many of these unique plants can be placed into the dicotyledonous class as follows: *Sium suave*, *Lycopus americanus*, *Utricularia vulgaris*, *Polygonum amphibium*, *Potentilla*, and *Ranunculus sceleratus* along with the monocot *Scirpus americanus*. In addition, the monocots *Beckmannia syzigachne* and *Glyceria grandis* and the dicot *Bidens ceruna* might also be viewed as unique Canadian contributions because of the restricted familial identifications that were possible for the grasses and composites in this current investigation.

About 70% of the discrete macrophytic taxa of the basin were recognized in each of the two inventories noted above with 40% observed in both of the studies. Each of these sampling efforts, in turn, provided 30% of the discrete identifications involving plants that were not recognized in the other surveys. Three of these unique Canadian identifications involved a species recognition of macrophytes that could only be keyed to genera in the Montana sampling program. Because of these features, the taxonomic results from the Saskatchewan studies have been reviewed for this project and are summarized in Table 2 since they do afford some further insights into the types of aquatic macrophytes that might be found in the Montana segment of the Poplar River drainage.

Montana Surveys. Similar to the macrophyte sampling program in Saskatchewan, this recent Montana survey additionally enhanced the aquatic plant taxa list of the Poplar region to a considerable extent by providing thirteen new identifications that had not been recognized in the Canadian work. These unique macrophytes can be listed as follows: *Anabaena variabilis*, *Oedogonium*, *Chara*, and *Nitella* of the algae; the Bryophyceae; *Scirpus acutus*, *Heteranthera dubia*, *Potamogeton foliosus*, *P. pectinatus*, *P. robbinsii*, *Sparganium angustifolium*, and *Zanichella palustris* of the monocots; and *Hippuris vulgaris* of the dicots. Three species of *Anabaena* were identified in the Saskatchewan surveys, although none of these specimens were keyed as *A. variabilis*. All of the non-charophytic macroalgae listed in Table 2, including *Oedogonium* and *Anabaena* spp., have been collected in earlier plant surveys on the Montana side of the basin (Bahls, 1977).

Several of the true macrophytes were also spotted during the Biological Resources Committee (BRC) plant reconnaissance of the upper East Poplar River in Montana (Tennant and Loch, 1979). This includes *Myriophyllum spicatum*, *Hippuris vulgaris*, and *Potamogeton richardsonii*, plus seven other macrophytes that were identified only to the generic level. Aquatic forms of *Polygonum* and *Potentilla* were included among these BRC genera, although they were not encountered as a component of this quantitative survey. *Polygonum amphibium* has been identified in Saskatchewan, as has two species of *Potentilla*, *P. anserina* L. and *P. norvegica* L., but these two *Potentilla* representatives were not included into Table 2 because they were classified as being riparian in nature. In any event, *Polygonum* and *Potentilla* appear to be quite rare components of the Poplar's aquatic macrophyte flora in Montana because of their non-collection in this more recent study.

In addition to the seven macroalgae listed in Table 2, approximately 300 other algal taxa of a wide variety of systematic proclivities and levels have been collected from the Montana-Saskatchewan sections of the Poplar streams. Detailed listings of these other taxa are presented in Bahls (1977) for Montana (primarily periphyton) and in Tennant and Loch (1979) for the entire drainage (including the phytoplanton). However, only the macroalgae that were actually collected during this project while making a transect run across the streams will be considered in this report with these algae thereby defined as a component of the streams' macrophytic communities.

Transect Nomenclatural Proficiency

Vegetational Naming. Although a fairly high taxonomic resolution was developed for the Poplar drainage macrophytes as a result of the laboratory-level keying efforts of several of the surveys, a much reduced naming capability had to be directed to the field recognitions of the project. The reasons for and details of these restrictions have been described previously, and the particular taxa that could be efficiently and accurately identified when making the transect runs are listed in Table 3. But because of the accessory laboratory evaluations of this inventory, and because of the keying data that are available from the other studies, a great deal of information is now on record which describes the likely taxonomic mixtures of these broader systematic groups.

Possible Vegetational Composition. Results from the Canadian surveys suggest that Equisetum arvense, Carex atherodes, Juncus balticus, and Polygonum amphibium probably make major contributions to the scouring-rush, true sedge, true rush, and smartweed stands respectively that are observed in the study area streams. Additional rationales along these lines are discussed below for the remaining systematic groups in Table 3. But in all of the cases of this kind where general, area-wide taxonomic identifications are transferred to more localized situations, the possible occurrence of other unrecognized and unknown species at these locations should be kept in mind as well as the nonexistence of an expected taxa. For example, Carex atherodes might actually be absent from the Montana study area in deference to the dominance of some other sedge species such as C. viridula and/or C. rostsata which are common sedge representatives in the State and found along many of its streams (Booth, 1950).

Bulrushes. Many of the bulrush specimens that were taken to the laboratory for identification could only be keyed to genus, although Scirpus acutus and S. validus were recognized in a fair number of the samples. These observations suggest that these two species dominate the bulrush stands of the Poplar drainage with S. acutus possibly somewhat more abundant than S. validus because of its slightly greater frequency in the accessory collections. Contrariwise, however, S. acutus was not listed by the Canadian researchers, and this feature could point to its reduced prevalence in the study area waters. Furthermore, the listing of S. americanus by these same references indicates that the American bulrush could also be a component of the Montana stands of this emergent plant group. But if S. americanus is present in Montana, it is probably quite rare since it was not spotted during the laboratory work of this inventory.

Grasses. Spartina pectinata was identified from among the many study specimens, and this indicates that it is one of the components of the graminid vegetation associated with the Poplar streams. In addition, the Canadian listings suggest that Beckmannia syzigachne and Glyceria grandis

Table 3. Distribution and qualitative abundance descriptions of aquatic macrophytes that were collected from the seven stream appraisal sites in the Poplar River drainage. The occurrence of these taxa in the Canadian portion of the basin is also noted.

		Inventory Appraisal Sites							
		East Poplar River					Upper Main Poplar	Middle Poplar	
Taxa or Algal Group	Canada	I	II	III	IV	VR-VP	VIR-VIP	VII	Overall Abundance
Bryophyceae	--	--	--	J	--	--:--	--:--	--	z
Equisetum sp.	p	--	J	--	--	--:--	--:--	--	z
Sagittaria cuneata	p	D	G	J	J	--:J	--:--	--	I
Carex sp.	p	H	H	G	F	F:F	I:H	H	G
Eleocharis sp.	p	G	H	H	G	H:G	--:I	I	H
Scirpus sp.	p	E	F	--	D	J:J	J:J	J	H
Juncus sp.	p	--	--	--	J	--:--	--:--	J	z
Poaceae	p	I	H	I	H	--:J	J:J	J	I
Heteranthera dubia	--	--	J	J	--	--:--	--:--	--	z
Potamogeton filiformis	p	J	J	J	--	J:J	J:J	J	J
P. foliosus	--	--	--	J	--	H:J	--:--	I	J
P. pectinatus	--	H	D	F	J	H:F	J:J	H	H
P. richardsonii	p	J	H	G	J	--:--	--:--	--	J
P. robbinsii	--	--	I	J	--	--:--	--:--	--	z
P. vaginatus	p	J	--	--	--	--:--	--:--	--	z
Sparganium sp.	p	H	H	J	I	--:--	--:--	--	J
Typha latifolia	p	--	E	--	J	--:--	--:--	--	J
Zanichella palustris	--	J	J	H	H	--:I	H:J	J	I
Asteraceae*	p	--	--	--	--	--:--	--:--	--	z
Myriophyllum spicatum	p	I	C	D	A	F:E	H:H	G	F
Hippuris vulgaris	--	I	H	J	J	--:I	H:I	J	I
Mentha arvensis	p	J	J	--	J	J:J	--:--	--	J
Polygonum sp.	p	q	q	q	--	--:--	--:--	--	z
Potentilla sp.	p	q	q	q	--	--:--	--:--	--	z
Characeae	--	I	H	C	--	--:F	--:--	J	I
Floating algae	p	J	H	H	H	I:G	H:H	H	H
Bottom algae	p	I	J	--	--	G:I	H:I	J	I
Bare Substrate	UK	C	H	E	G	A:C	AA:AA	AA	C

R-Riffle segments and p--pool segments. Macrophyte abundance and substrate frequency classes A to J: A--very high abundance or frequency to J--very low abundance or frequency. AA--Denotes a markedly high occurrence of bare stream bottom materials. z--Denotes a distinctly low overall plant abundance. p--Identified in the Saskatchewan portion of the drainage at the same or lower systematic levels. *Recognized in one accessory collection from station II but not tabulated in any of the transect runs. q--Identified in other Montana surveys from the upper part of the East Poplar but not collected in this particular project. UK--Unknown; information not available.

could also comprise some of the aquatic grass tabulations that were made in the study region. Of course, no direct information is available concerning the relative importance of these three taxa, and other aquatic grass species could also be abundant in and along these waters although not recognized under the field keying restrictions of this post-1980 survey.

Spike-rushes and Bur-reeds. Identifications in Saskatchewan and Montana both suggest that *Eleocharis acicularis* and *E. palustris* comprise the spike-rush stands in the Poplar streams with *Sparganium eurycarpum* dominating the bur-reed growths. No quantitative data are on hand concerning the comparative abundances of these two spike-rush species, but the limited collections of *S. angustifolium* in Montana and the nonrecognition of this bur-reed in Saskatchewan indicate that this species is a minor component of the Poplar's aquatic vegetation. Field observations of the submersed and elongate, hair-like stem morphology of *E. acicularis*, termed *forma inundata* (Fassett, 1969), point to the fact that this species is a significant component of the underwater stands of this amphibious genus. However, *E. palustris* also has a submersed stage, and both of the spike-rush species can be emergent in character so that no broad abundance separations could be made for these two taxa on the basis of their general growth forms. As the most likely case, each of these species is probably fairly prevalent in the Poplar basin.

Characeae. Both *Chara* and *Nitella* have been collected from streams in the Montana section of the Poplar drainage, and the relative frequency of these identifications suggest that *Chara* is the more predominant form. But the retrieval of a fair number of *Nitella* samples from these same waters indicate that this charophyte is also a fairly abundant plant within the study area. As a somewhat surprising observation, neither *Chara* or *Nitella* had been listed as a part of the Poplar algal collections obtained from the Saskatchewan reaches of the basin, nor were they recorded as a component of the algal samples that were obtained downstream on the drainage during the earlier Montana surveys (Tennant and Loch, 1979).

Direct taxonomic information is not available by which to further delineate the nomenclatural features of the moss specimen, and this is also the case for the composite and the aquatic form of *Potentilla* which was observed in the East Poplar River of Montana. Either *P. anserina* or *P. norvegica*, as identified in Canada, might have a minor in-water phase that could have been recognized during BRC reconnaissance of the East Poplar, although Fassett (1969) points to the occurrence of *P. palustris* as a conceivable option. The Saskatchewan macrophyte listings also indicate that the composite collected during this study could possibly have been *Bidens ceruna*, but this assumption is largely conjectural given the large size of the Asteraceae Family with its many aquatic representatives. In contrast, some degree of taxonomic detail is on record for the floating and bottom macroalgae groups that are listed in Table 3.

DISTRIBUTION AND ABUNDANCE

Tabular Considerations

In addition to its field-related taxonomic listing, Table 3 was designed to illustrate the distributional features of the Poplar aquatic plants as they were identified at the seven appraisal sites in Montana and spotted in the Canadian part of the basin. This includes both the true macrophytes (higher plants and charophytes) plus the two lower plant groups. As a related observation to the table, and unlike the macroalgae, the true macrophytes were observed to be largely absent from the lower Poplar mainstem reaches and from the Poplar West Fork. However, the presences and absences of the macroalgae genera in these lower segments of the drainage and in Canada are summarized in Table 4, as are their occurrences at the inventory stations, and the distributions of the individual generic components of the two algal groups will be reviewed in a subsequent section of this writing. Table 4 also illustrates the generic compositions of the floating and bottom algae, and these aspects too will be discussed at a later time.

To facilitate the comparative applications of this report, both Tables 3 and 4 contain qualitative abundance summaries of the two macroalgae groups as they occurred at the different stream locations. These abundances are expressed in the form of ten defined categories, and the frequency of occurrence of bare substrates is also noted in the two tables via these same categories for each of the sampling stations. Table 3, in turn, contains the abundance summaries of the true macrophytic plants.

The ten prevalence classes were developed on the basis of the weighted station canopy cover values that were calculated for the different taxa. The "A" category, therefore, ranges between 30% and 35%, the "B" category between 25% and 30%, and so on in five percent increments to the "G" class which ranges between 3% and 5%, the "H" class between 1% and 3%, "I" between 0.5% and 1%, and "J" between 0% and 0.5%. The "AA" category denotes a nonvegetated stream bottom frequency in excess of 43%. The particular weighted canopy cover values of the appropriate Poplar macrophytes, excluding the non-charophytic algal genera, and the quantitative aspects of the study will be considered in more detail in a following chapter. The qualitative presentation of this section is intended as an overall synopsis of the relative abundance and distributional characteristics of these aquatic plants.

Taxa Prevalence Classification for the Entire Drainage

Rare Taxa Delineations--Higher Plants. A large number of the true aquatic macrophytes that were recognized in the Poplar River basin can be classified as being generally quite rare in the Montana study area, and this rarity can be viewed at three different stages as follows: First, the taxa that were identified in Saskatchewan but not collected in the Montana inventories could be totally absent from the latter region, or if they do happen to be present, they probably occur in extremely low abundance levels. The taxa that can be placed into this first grouping are *Scirpus americanus*, *Sium suave*, *Lycopus americanus*, *Utricularia vulgaris*, and *Ranunculus sceleratus*, and these five aquatic plants appear to represent the rarest macrophytes that might possibly be found in Montana's Poplar streams.

As a second grouping, the taxa that were identified in Canada and/or in some of the Montana inventories while not being encountered during the many transect runs of the study can also be classified as relatively rare macrophytes for the project region. *Potentilla* sp., *Polygonum amphibium*,

Table 4. Distribution and qualitative abundance descriptions of the Poplar River drainage macroalgae that were collected in this inventory from the seven stream appraisal sites. The occurrence of these taxa in the Canadian portion of the basin is also noted as well as their Montana collection in other studies.

		Inventory Appraisal Sites								Other Montana Locations	
		East Poplar River					Upper Main Poplar	Middle Poplar			
Algal Group and Taxa	Canada	I	II	III	IV	VR-VP	VIR-VIP	VII	Overall Abundance	West Fork Poplar	Lower Main Poplar
Floating Algae	UK	J	H	H	H	I-G	H-H	H	H	UK	UK
Anabaena spp.	p	p	--	--	X	p	p	p	UK	p	p
A. variabilis	--	--	--	--	X	--	--	--	UK	--	--
Cladophora	p	p	--	--	--	p	p	p	UK	p	p
Mougeotia	p	p	X	X	--	--	--	Xp	UK	p	--
Oedogonium	--	--	--	--	--	--	--	Xp	UK	--	--
Rhizoclonium	p	p	--	--	--	Xp	Xp	X	UK	--	--
Spirogyra	p	--	--	--	X	X	X	X	UK	p	--
Tribonema	p	--	X	X	X	--	--	--	UK	--	--
Bottom Algae	UK	I	J	--	--	G-I	H-I	J	I	UK	UK
Anabaena spp.	p	p	--	--	--	p	p	p	UK	p	p
A. variabilis	--	--	--	--	--	--	--	--	UK	--	--
Cladophora	p	Xp	--	--	--	p	p	p	UK	p	p
Mougeotia	p	p	X	--	--	--	--	p	UK	p	--
Oedogonium	--	--	--	--	--	--	--	p	UK	--	--
Rhizoclonium	p	p	--	--	--	Xp	Xp	--	UK	--	--
Spirogyra	p	--	X	--	--	--	X	X	UK	p	--
Tribonema	p	X	X	--	--	--	--	X	UK	--	--
Bare Substrate	UK	C	H	E	G	A-C	AA-AA	AA	C	UK	UK

R--Riffle segments and P--pool segments. Algal abundance and substrate frequency classes A to J: A--very high abundance or frequency to J--very low abundance or frequency. AA--Denotes a markedly high occurrence of bare stream bottom materials. UK--Unknown; information not on hand for judging the abundance or frequency classifications of these categories. X--Macroalgae collected in this inventory and relegated to the floating and bottom groups, but data not available by which to determine the riffle-pool preferences and the abundance features of the individual taxa. p--Algal taxa collected in Canada and in other Montana studies with information lacking concerning their floating-bottom and riffle-pool characteristics and their abundance levels in terms of the A to J classes; such accessory samples were not obtained from stations II to IV.

Bidens ceruna (Asteraceae), and Sparganium angustifolium fall under this particular heading. But at the same time, several of the higher plants that were recognized during the field tabulations can too be viewed as being relatively rare in the project area because of their limited distributions and their low canopy cover levels, although they are probably more common than the organisms that fall into the first two categories. The six representatives of this third assortment plus three of the taxa that fall into the second set are denoted with a "z" designation in the "overall abundance" column of Table 3. Examples are Heteranthera dubia and Potamogeton vaginatus.

Rare Taxa-Abundant Taxa Comparisons. At least 35% of the discrete aquatic plant taxa that were recognized for the study area can be classified as being relatively rare true macrophytes in the Poplar streams with limited distributions and reduced abundance levels, while at least 42% of these discrete organisms can be viewed as being fairly prevalent on the Montana side of the basin. The remaining 23% are discussed below. The more abundant plants are pinpointed in Table 3 with the "F-J" letter designations in the "overall abundance" column, and examples are Sagittaria cuneata, Potamogeton pectinatus, and Hippuris vulgaris. A fairly large number of these "F-J" organisms were observed at each of the sampling sites in contrast to the much smaller selection of rare macrophytes that were spotted at any one of the stream locations. As a result, the kinds of plants that can be tagged with a prevalent designation will receive the greatest amount of attention in this report. Rare taxa were not collected in this study from stations V and VI, and these rarer aquatics demonstrated their greatest frequency of occurrence in Montana in the upper reaches of the East Poplar River.

The abundance and distributional characteristics of the three individual grass species are largely unknown because of the lack of taxonomic data. However, since the Poaceae were observed to be a fairly common component of the study area's aquatic vegetation on a familial basis, these three taxa are probably best viewed as being relatively abundant in order to achieve an accounting balance. The graminids, thereby, account for 7% of the discrete and abundant macrophytic taxa that were identified for the region. Furthermore, the macroalgae make up another 16% of the discrete taxa, and as illustrated in Table 4, at least four and possibly five of these plants (Mougeotia, Rhizoclonium, Spirogyra, Tribonema, and possibly Cladophora) can be placed into the abundant plant category with the remaining two discrete members of this group (Oedogonium and A. variablis) appearing to be fairly rare throughout the Poplar drainage. Thus, when the macroalgae and Poaceae are also considered, the rare taxa-abundant taxa split for the study equals about 40% and 60% respectively.

As noted, 25 or 26 discrete taxa of aquatic macrophytes, depending upon the Cladophora classification, were judged as being relatively abundant in the Poplar drainage, and these more prevalent plants, as distinct from the rare forms, can be additionally subdivided into five classes (dominant, subdominant, prevalent, common, and slightly common) on the basis of their overall canopy cover levels in the basin and/or on the basis of their distributions through the seven appraisal sites. These five plant combinations coupled with the three types of rare plants that were defined previously (extremely infrequent--category one, very infrequent--category two, and infrequent--category three) allow the separation of the Poplar macrophytes into eight fairly distinct prevalence categories. The following discussion will focus upon the more abundant forms, and a tabular summary of the taxa comprising each of these eight classes is presented in Table 5.

Abundant Taxa Delineations. The dominant class describes two ubiquitous true macrophytes (Myriophyllum spicatum and Carex sp.), having relatively high overall biomass levels, that were observed at all of the appraisal sites. M. spicatum had particularly high canopy cover values, and this particular taxa represents the supra-dominant aquatic plant of the study region. The subdominant plants, in turn, had lower canopy cover levels than the dominant forms, although the numbers were still fairly distinctive, and these taxa were also found at almost all of the sampling locations. Along with Eleocharis spp., Scirpus spp., and Potamogeton pectinatus, the floating algae as a group are best included into this subdominant category. But on a generic basis, the less ubiquitous individual algal taxa would have to be placed into one of the other classes.

At a third abundance level, aquatic plants included into the prevalent category had yet lower canopy cover levels than the subdominant macrophytes, but they were still fairly conspicuous in the study area streams by virtue of being present at most of the sampling sites. The grasses, Potamogeton filiformis, Zanichella palustris, Hippuris vulgaris, and the bottom algal group can be classified as members of this particular set. But in the latter case, at least one of the individual bottom genera (Cladophora) would have to be placed into another category in terms of this survey because of its restricted distribution through the macrophyte communities. The taxa-specific class delineations of the algae will be described below, and on an overall basis, the floating thallophytes were found to be more prevalent in the study area than the bottom forms.

The common and slightly common abundance classes are distinct from the other three assortments by the fact that the common-slightly common taxa were observed to be absent from a large number of the appraisal sites, and this absence is most distinct with the plants that fall into the latter category. However, the common and slightly common macrophytes were seen to be suitably abundant at the few stations at which they were found so as to register an adequately high overall biomass level that is comparable to the canopy cover values of the plants falling into the prevalent clss. Typha latifolia is particularly distinctive in this regard. Sagittaria cuneata, Potamogeton richardsonii, Sparganium eurycarpum, Mentha arvensis, and the charophytes can be classified as the common macrophytes of the Poplar drainage, while Potamogeton foliosus and T. latifolia can be viewed as the two components of the slightly common group. As illustrated in Table 5, several of the more abundant taxa described above are representative of unique contributions to the basin's flora as a result of this recent study since these macrophytes were not collected as a part of the Saskatchewan sampling programs.

Lower Plant Delineations. With reference to the macroalgae genera of Table 5, these taxa were assigned to a particular abundance class on the basis of their distributions through the study region as illustrated in Table 4. Therefore, Mougeotia, Rizoclonium, Spirogyra, and Tribonema were

Table 5. Prevalence classification of aquatic macrophytes in the Poplar River drainage of Montana.

Abundant--Ubiquitous Dominant

Myriophyllum spicatum
Carex (=C. atherodes?)

Abundant--Ubiquitous Subdominant

Potamogeton pectinatus*
Floating Algae Group
Eleocharis acicularis
Eleocharis palustris
Scirpus acutus*
Scirpus validus

Abundant--Ubiquitous Prevalent

Poaceae
Beckmannia syzigachne#
Glyceria grandis#
Spartina pectinata
Potamogeton filiformis
Zanichella palustris*
Hippuris vulgaris*

Bottom Algae Group
Anabaena spp. A
Cladophora A
Spirogyra
Tribonema
Mougeotia
Rhizoclonium

Abundant--Nonubiquitous Common

Sagittaria cuneata
Chara*
Nitella*
Potamogeton richardsonii
Sparganium eurycarpum
Mentha arvensis

Abundant--Nonubiquitous Slightly Common

Potamogeton foliosus*
Typha latifolia

Rare-Infrequent

Potamogeton robbinsii*
Heteranthera dubia*
Equisetum (=E. arvense?)
Juncus (=J. balticus?)
Potamogeton vaginatus
Cladophora B
Oedogonium*
Bryophyceae*

Rare--Very Infrequent

Asteraceae
Bidens ceruna#
Anabaena variabilis B*
Sparganium angustifolium*
Polygonum (=P. amphibious?)#
Potentilla spp.#

Rare-Extremely Infrequent or Absent

Scirpus americanus#
Sium suave#
Lycopus americanus#
Utricularia vulgaris#
Ranunculus sceleratus#

*Collected in this project but not identified in the Saskatchewan surveys.

#Not collected in this project but identified in other Montana and/or Saskatchewan surveys.

A--Prevalence classifications based on all of the study area inventories.

B--Prevalence classifications based only on the results of this present inventory.

assigned to the prevalent category since they were not collected from two or three of the stations as was the case for the true macrophytes that were similarly placed into the prevalent class. The abundance levels of the two algal groups also indicate that this is a reasonable classification. But in spite of such generic absences from some of the stations, the floating algal as a group were still obtained from each of the appraisal sites because one genus acted to supplant another in going from one location to a different site, and these taxa shifts were also noted for the bottom algae to some extent. Because of this fact, the floating algae as a generic combination were given a higher abundance designation than the individual taxa, although the bottom algae were not so placed because of their absence from two of the stations.

Cladophora, in turn, can be assigned to either the prevalent or the infrequent class depending upon which of the studies are being reviewed. But in terms of the macrophyte communities that are described in this project, _Cladophora_ should be viewed as a rare representative as is the case for _Oedogonium_ because of their infrequent collections. For the same reason, _Anabaena variabilis_ was given a very infrequent rating in light of the low collection success of this inventory, but the genus _Anabaena_, like _Cladophora_, can be viewed as a prevalent taxa if the more successful sampling efforts of the earlier surveys are considered. These extra options for _Anabaena_ and _Cladophora_ are shown in Table 5.

As indicated by these discussions, the aquatic macrophyte communities of the Poplar River basin are not only quite diverse floristically, but they also demonstrate a wide latitude of abundance and distributional variations among the different taxa that comprise these associations, and this includes the thallophytic type of plant. These features then act to impart a considerable amount of extra color to the floral mosaics that can be found in the lotic waters of the study region. In addition, the inter-station abundance variations of several of the aquatic taxa also contribute to the changing floral patterns that are seen in the Poplar streams.

Taxa Prevalence by Appraisal Site

Generally Consistent Taxa. The previous section of this report generally described in qualitative terms the overall abundance levels of the various aquatic macrophyte taxa in the Poplar drainage with reference to their average canopy cover values through the entire study area. The abundance variations among the taxa were also noted, and as an added factor, several of these organisms demonstrated fairly distinct differences in biomass among the several appraisal sites as is illustrated in Table 3. But at the same time, a fair number of these plants did not reveal any marked variations of this kind after making the many inter-station comparisons.

This nonvariable class of macrophytes includes all of the rare taxa since these plants were consistently observed at extremely low abundance levels when they happened to be uncovered at one of the stations, and several of the more prevalent plants also provided fairly uniform and consistent canopy cover values among the seven stream locations. The most obvious examples of this latter case are _Potamogeton filiformis_ and _Mentha arvensis_ with these two taxa either absent or relatively non-abundant at each of the sampling sites. In addition, the two macroalgae groups, although considerably more abundant than P. filiformis and M. arvensis, also demonstrated largely unchanging biomass levels through the stream reaches with comparatively minor inter-station differences. This consistency was most obvious for the floating algae since the bottom forms were found to be more common in the riffle reaches over the ponded segments while being absent from two of the stations. The most distinct feature of the floating algae was found in their relatively low occurrences at station I, and they tended to be somewhat more common in the pools over the riffle sections of the streams. However, detailed delineations along these lines could not be directed to the individual algal genera because of the lack of any specific abundance information.

Relatively minor inter-station biomass variations were also obtained for Hippuris vulgaris, Zanichella palustris, the grasses, and Eleocharis spp. In the case of the first species, these differences did not appear to occur in the form of any distinct patterns or trends, while Z. palustris was seen to be slightly more abundant in the middle East Poplar reaches than in the upper and lower sections of this river. Furthermore, Z. palustris had comparatively low canopy cover levels in the main Poplar and in the Middle Fork. In contrast, the grass and Eleocharis taxa tended to have slightly higher canopy covers in the upper East Poplar than in the other inventoried segments. However, these biomass differences were observed to be relatively small, and much more striking examples of inter-station abundance discrepancies can be found in relation to some of the other macrophytic plants.

Obviously Variable Taxa. Myriophyllum spicatum provides the most pronounced example of macrophytic canopy cover variations among the several study area sampling stations. This submersant plant was distinctively abundant in the lower part of the East Poplar River, particularly at station IV, while being much less prevalent in the upper East Poplar at the international boundary (station I), in the main Poplar, and in the river's Middle Fork (Figure 1). In addition, inter-station biomass differences were also quite marked for Sagittaria cuneata and the bur-reeds, although these plants demonstrated a different pattern of abundance change than the supra-dominant macrophyte of the drainage. That is, these amphibious aquatics had relatively high abundances in the upper East Poplar, primarily at station I, and this condition sharply contrasted with the absence of the arrowheads and the bur-reeds from the lower East Poplar and/or from the middle Poplar and the mainstem reach of the river.

In contrast to S. cuneata and Sparganium sp., most of the other macrophytes showing obvious abundance variations among the appraisal sites revealed patterns that were most similar to the one described for the water-milfoil with relatively low canopy covers at station I, with much higher canopy covers at one of the other East Poplar stations, and with comparatively low biomass levels at the non-East Poplar locations. However, some minor and unique deviations to the basic water-milfoil pattern did become evident in all of these related macrophytes, and such discrepancies can be briefly outlined as follows for each of the plants: Carex--abundance peaks at stations IV and V rather than IV alone; Scirpus--absent from station III with a relatively high abundance at station I; Potamogeton pectinatus--abundance peak at station II rather than IV; P. richardsonii--abundance peak at station II with its absence from stations V-VII; Characeae--abundance peak at station III with its absence from station IV and the main Poplar River.

One other basic pattern of abundance difference among stations became evident in the study area streams in the form of two general modifications. In this instance, individuals of a macrophytic taxon, while being absent from most of the appraisal sites, were unexpectedly encountered at one or two of the stations with the taxon producing relatively high canopy cover values at these specific locations. Potamogeton foliosus affords one example of this type of pattern (Table 3) in having fairly high abundance levels in the extreme lower East Poplar River and in the Middle Fork while being largely absent from the remaining East Poplar reaches and the main Poplar River. Typha latifolia provides the other modification to this same basic theme, and this macrophyte is additionally distinct for the region in having quite high abundances at only one of the sites (station II) while being largely unrecorded for the rest of the stations. Nevertheless, both of these plants can still be rated as generally common for the Montana portion of the basin regardless of these many absences because of the high canopy covers that were obtained at the stations at which they were found. These unique occurrences then produced the somewhat high mean canopy cover percentages of the two macrophytes for the entire drainage.

Riffle and Pool Comparisons. In terms of the fifty riffle to pool combinations that are possible in Table 3 for the true macrophytes at stations V and VI, five general comparative statements can be made with reference to the riffle-pool aspects of the survey, and these can be listed as follows: (1) certain of the taxa were absent from both of the segments in 56% of the cases, (2) had identical abundance categories in both of the reaches in 18% of the cases, (3) were absent from the riffle reach but present in the ponded reach in 12% of the cases, (4) were present in both of the segments but more abundant in the ponded over the riffle reach in 8% of the cases, and (5) were present in both of the segments but less abundant in the ponded versus the riffle reach in the last 6% of the comparisons. In the main, and based on these statements, the ponded sections of the streams appear to be somewhat more conducive to the establishment and development of aquatic macrophytes than the sister riffle reaches, although the magnitude of the riffle-pool differences are not all that distinct in relation to the direct comparisons of this kind that were made available through the design of this recent project.

In view of the 56% absentee factor, the lack of clarity in the riffle-pool differences that was noted above could have been related to the low macrophyte canopy cover levels that happen to generally characterize these two particular stations (V and VI) regardless of the habitat. Therefore, if additional riffle-pool analyses could have been made at the other sites during the inventory, such differences would be expected to be significantly greater in favor of the pools at those stations that happened to have a relatively plush macrophyte development in the ponded segments. Unfortunately, these extra comparisons were not feasible for the survey because of the morphometric nature of the Poplar streams. In any event, the quantitative aspects of the riffle-pool comparisons that are on hand for the study will be considered later.

The riffle-pool differences of the two macroalgae groups have been briefly described previously. That is, the bottom algal tended to be more somewhat abundant in the riffle over the ponded segments while the reverse was generally true for the floating forms. These relationships might be anticipated in view of the disparate current velocities that are characteristic of these two habitats; however, as shown in Table 4, such differences in canopy cover were not particularly distinct for the floating algal in all of the comparisons.

Nonvegetated Substrate Comparisons. With some exceptions, the aquatic macrophytes that did demonstrate some degree of abundance variability through the sampling stations were observed to have their highest canopy cover values in the middle parts of the East Poplar River (stations II, III, and IV) instead of the extreme upper and lower sections of this stream (Table 3). Furthermore, taxa canopy cover levels were generally lower in the main Poplar and in the Middle Fork than in the more eastern fork of the river. But in a contrary fashion, the frequency of occurrence of bare substrates was greater in the middle Poplar and in the main river than in the East Poplar, and bare substrates were particularly distinctive in the system's mainstem reach. Of the five East Poplar stations, this feature was most prevalent at the upper and lower locations.

Except for stations II, III, and IV, the bare substrate frequency of a sampling site was greater than the percent occurrence of any given taxa. But in most of the instances the percent occurrence of the vegetated transect points, which includes all of the station taxa, greatly exceeded the percent occurrence of the nonvegetated stream bottom materials. Station VIP provided one exception where its vegetative canopy cover was significantly lower than its bare substrate frequency, and with respect to station VII, vegetative canopy cover and bare substrate frequency were closely equal. Similar to the observations of macrophyte canopy cover therefore, the amount of nonvegetated stream bottom materials at the different appraisal sites also showed a wide range of variation as is evidenced by the station II to VI comparison in Table 4, and this aspect also contributes to the differing floral mosaics that can be seen in the Poplar drainage streams.

Macroalgae Genera

Algal Group Compositions. The numerous floating and bottom macroalgal collections of the project produced seven genera with some of these organisms widely distributed throughout the Poplar drainage but with others observed at only a few locations. This relatively low retrieval success in terms of the number of algal taxa collected was generally unexpected in view of the 48 planktonic, 11 periphytic, and 28 facultative non-diatom algal genera that had been listed for the Poplar River basin by other researchers (Tennant and Loch, 1979). That is, a somewhat more extensive intermixing of a fair number of the less common genera with a few of the more dominant forms had been anticipated for the samples in light of this listing in contrast to what is shown in Table 4. But in any case the reduced numbers of thallophytic taxa that were obtained during this inventory are no doubt reflective of the inherent restrictions that were imposed on the algal work by the defined boundaries of this macrophytic survey, and these boundaries have been outlined earlier.

Because of the design of the sampling program, the algal samples that were obtained from the transect locations were largely mono-floristic in character with an average of 1.3 genera per field sample. About three-fourths of the collections had only one representative, and the sampling stations only averaged 2.3 algal genera per any of the algal groups so that the thallophytes did not make an overriding contribution to the diversity of the macrophyte communities. However, a higher algal collection success on par with that of the other inventories would have been obtained for this project if the collecting efforts had been specifically focused upon this particular group of plants rather than the macrophyte associations.

As indicated in Table 4, Anabaena variabilis and Oedogonium of the less frequently recognized taxa were only obtained in the floating algal samples while Cladophora was only secured as a member of the bottom collections. But the other four genera of macroalgae, showing a higher rate of retrieval, were collected as representatives of both of the algal groups, although these four organisms did demonstrate some degree of preference for one habitat over the other.

Two of the macroalgae, Mougeotia and Rhizoclonium, provided their greatest frequency of collection in the floating samples with adjusted floating: bottom percentages of 77%:23% and 61%:39% respectively. Tribonema and Spirogyra, in contrast, provided their greatest frequency of collection in the bottom samples with adjusted floating:bottom percentages of 29%:71% and 41%:59% respectively. The mathematical adjustments that were required in order to make such percentage manipulations involved a correction for the larger number of floating algal samples that were obtained from the Poplar region over the bottom collections. As suggested by a comparison of these refined percentage values, Mougeotia and Tribonema generally demonstrated a more marked degree of confinement to either a neustonic or a benthic life-style respectively than was the case for Rhizoclonium (somewhat neustonic) and Spirogyra (somewhat benthic), and of these genera, Spirogyra revealed the greatest flexibility for varying its community position in the Poplar streams. The possible life-style restrictions of A. variabilis, Oedogonium, and Cladophora have been outlined before, although the data are scanty for these particular forms.

Inter-Station Variations of the Rare Taxa. In relation to the field work of this study, Cladophora and the blue-green algal genus Anabaena, which was identified as A. variabilis in these more recent keying efforts, were each obtained from only one of the appraisal sites (stations I and IV respectively). This low level of retrieval was surprising for the two genera since the earlier aquatic plant surveys of the same area had indicated that these same two algae should be widely distributed throughout the Poplar drainage with their distributions including portions of the drainage in Saskatchewan plus all of the major river segments in Montana, i.e., the East, Middle, and West Forks along with the upper and lower portions of the main Poplar River (Table 4). Nevertheless, the results from this inventory point to the fact that these two plants, though widespread, were not very important components of most of the stream's macrophyte communities as they were examined under the confines of this particular project. As a result, the generic abundances of Cladophora and Anabaena that were described in the other Poplar surveys most have been expressed by the plants in some fashion apart from these macrophytic assemblages per se; e.g., they could have been occupants of various non-macrophytic and non-evaluated riffle reaches. As another option, the species A. variabilis that was collected in this study appears to be quite rare in the Poplar basin as intimated previously, and this feature could also account for the reduced collection frequency of this specific organism.

The green algal genus Oedogonium also afforded a low collection frequency for the study as it was uncovered at only one of the appraisal sites. But unlike Cladophora, this rarity is substantiated by the low collection success of this taxa in the other basin inventories as illustrated in Table 4. Oedogonium, thereby, appears to be restricted to the Middle Fork of the Poplar River in Montana where it was observed as a member of the floating algal group in this particular stream.

Inter-Station Variations of the Prevalent Taxa. In contrast to the algal genera noted above, Mougeotia, Rhizoclonium, Spirogyra, and Tribonema were each collected with a fairly distinct level of regularity from most of the appraisal sites of this inventory, and this would indicate that these four plants do make some type of noticeable contribution to the Poplar's macrophyte communities. Furthermore, data from all of the investigations suggest that these four taxa are fairly ubiquitous throughout the Poplar drainage, although they were not observed to be as widespread as the less macrophyte-prone Cladophora and Anabaena genera. On this basis, therefore, three basic distributional types of algae can be delineated from the surveys as follows: (1) the extremely widespread but non-macrophytic taxa that were not generally identified as integral parts of most of the macrophyte communities; (2) the moderately widespread macrophytic taxa that were recognized as distinct components of these communities; and (3) a highly restricted taxon that was found to be a part of the macrophyte community at the single station at which it was found.

The distributions of algal types one and three that were defined above have been described in the previous paragraphs. As an accessory item, a fourth class of algae can be established that would include the many ubiquitous and non-ubiquitous taxa that were identified in the other studies of the drainage but not collected from the macrophyte associations that were examined in the context of this particular project.

Of the four macrophytic and widespread macroalgae that were sampled during this more recent survey (type two), Rhizoclonium revealed the most restricted distribution among the stations in being uncollected from several of the stream segments, including the middle East Poplar and the West Fork system. However, Rhizoclonium was identified in Saskatchewan, in the Middle Fork, in the extreme upper East Poplar of Montana, and in the extreme lower East Poplar-upper main Poplar River reaches of this same State (Table 4).

Tribonema also had a fairly delimited distribution in the basin, and it was largely confined to the upper and middle East Poplar segments and to the Middle Fork reach. Furthermore, this particular genus was unique among the macrophytic macroalgae of the project in not being identified in the earlier Montana algal surveys, although it had been collected in Canada. In contrast to the case described for Cladophora, therefore, this feature suggests that the eventual recognition of Tribonema in the drainage might have been dependent upon its close association with the sampled macrophytic communities. Mougeotia, however, was observed in all of the Montana and

Canadian inventories, and it was found in the following Poplar streams: the upper East Fork, the Middle Fork, and the West Fork. But Mougeotia was not located in the lower East Poplar or the Poplar River mainstem.

Spirogyra appeared to be the most widespread of these prevalent algae in being collected from most of the Poplar segments. But in opposition to Cladophora and Anabaena, neither Spirogyra or the other three macrophytic thallophytes were found in the lower portion of the main Poplar River. Thus, each of the seven macroalgae demonstrated a somewhat different distributional pattern through the Poplar drainage, and they thereby also contributed to some extent to the inter-station floral variations that were seen in the basin.

Floral Classification by Appraisal Site

The floristic variations and the taxa and total plant abundance differences among the sampling stations were found to be adequately distinct so that the various appraisal sites could be separated from each other on the basis of a particular floral "fingerprint" that became evident for each of the stream locations within the Poplar drainage. The specific "fingerprint" that happened to categorize any one of these stations can be illustrated by simply listing and ranking the top three or four taxa at that location, including the ties, on the basis of the A-J abundance classes that are summarized in Table 3. To enhance these separations, this same listing should also include the bare substrate expression of a site if and when its prevalence percentage happens to be adequately high so as to fall within or beyond a set of macrophyte rankings. Such a floral classification is presented in Table 6, and as indicated in this table, the various Poplar stations do exhibit a great deal of floristic difference from each other as expressed by this assessment approach.

As one example of these inter-site floral differences, station I can be readily recognized from all of the other appraisal sites by its high abundance of Sagittaria cuneata and by the relatively low canopy cover value of Myriophyllum spicatum. As another example, station II can be easily separated floristically from station VIP by the high levels of pondweeds and cat-tails and the relatively low levels of bare substrates and floating algae in the first case versus the relatively high canopy cover contributions of the sedges and Hippuris vulgaris and the low abundances of the bulrushes at the latter site. Of course, numerous other comparisons along these lines can be made for the remaining 27 station combinations that are possible for the study, and these other floral differences are illustrated by the table. Furthermore, the unique occurrences of some of the rare taxa at a few of the stations, such as Oedogonium, Heteranthera dubia, and Potamogeton robinsii, also contribute to these floristic separations.

IMPORTANCE OF THE POPLAR AQUATIC MACROPHYTES TO WILDLIFE AND FISH

Many of the abiotic environmental factors that can affect aquatic organisms often have a detrimental influence both when at extremely high and at extremely low levels, and a maximum benefit is typically derived from the factor at some intermediate and optimum intensity value. This same trichotomous relationship is also true of many of the biotic factors, and a perspective of this kind has to be directed to the macrophyte communities of

Table 6. Floral Classification of the Poplar drainage appraisal sites with reference to the dominant taxa compositions of their aquatic macrophyte communities.

Station@	Dominant Categories (Bare Substrates and/or Taxa)
I-EP	Bare Substrates--*Sagittaria**--*Scirpus*--*Eleocharis*
II-EP	*Myriophyllum*--*P. pectinatus**--*Typha**--*Scirpus*
III-EP	Characeae*--*Myriophyllum*--Bare Substrates--*P. pectinatus*
IV-EP	Myriophyllum*!--*Scirpus**--*Carex*--*Eleocharis*
VR-EP	Bare Substrates!--*Carex*--*Myriophyllum*--Bottom Algae*--*P. pectinatus*
VP-EP	Bare Substrates!--*Myriophyllum*--*Carex*--*P. pectinatus*--Characeae
VIR-MP	Bare Substrates!--*Zanichella*--*Myriophyllum*--*Hippuris*--Macroalgae
VIP-MP	Bare Substrates!--*Carex*--*Myriophyllum*--Macroalgae--*Eleocharis*
VII-MF	Bare Substrates!--*Carex*--*P. pectinatus*--Floating algae

@EP--East Poplar stations, MP--main Poplar station, MF--Middle Fork station, R--riffle, and P--pool.

*--Denotes a distinctively high station prevalence for the category.

!--Denotes a distinctively high category prevalence for the station.

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the Poplar drainage streams as they might adversely or beneficially influence the wildlife and fishery populations that use and/or inhabit these waters.

As noted previously, extensive weed beds of submersed macrophytes and dense stands of emergent aquatic plants can have an adverse effect on the related animals by causing a general deterioration of their habitats. But many of these same plants can be beneficial when at lower and more optimum abundance levels by providing the animals with at least some of their food and shelter needs. At the same time, such food and shelter availabilities are reduced when the essential macrophytes are at low abundance in relation to any of the particular organisms that might happen to utilize any one or more of the plants. Thus, macrophytic associations can be viewed as positively or negatively important to a stream system depending upon the density and composition of these communities, and an evaluation of the potential negative status of the aquatic plants in the study area represents one of the objectives of this inventory and the reason for conducting repeat surveys in future years.

On the positive side, Fassett (1969) has conducted an extensive literature review dealing with the potential importance of different aquatic plants to a variety of wildlife and fish species. Table 7 presents a summary of Fassett's findings as they apply to the particular aquatic macrophytes that are found in the Poplar River drainage and to the various animals (including birds and fish) that are important to this region and/or to Montana as a whole. Supplemental information along these lines that is available in Booth (1950) has also been incorporated into the table. Wildlife listings that are specific for the Poplar basin are presented in Stewart (1979) and DeSimone (1979 and 1980). However, some animals that are

Table 7. Summary of the potential importance of the different aquatic maccrophyte taxa observed in the Poplar River drainage in relation to the use of these plants by wildlife and fish (the first of three pages). Information taken primarily from N. C. Fassett's A Manual of Aquatic Plants (1969).

Cladophora: Often acting as a food producer for fish, this algae is at its best in this regard when it is located in faster water, especially for rainbow trout.

Spirogyra: Eaten by wildfowl, it is sometimes the preferred food of deer.

Characeae: Often important for wildfowl, probably because of the minute aquatic animals that are harbored by this vegetation, these plants also provide fair shelter and are excellent producers of food for young trout and certain other fish species.

Bryophyceae: Probably of no major value to fish and other higher animals, although there are mixed reports on the use of aquatic mosses for food.

Equisetum: Providing some food for various wildfowl species, including ruffed grouse, the scouring-rushes are mainly utilized by geese.

Sagittaria: Wildfowl will eat the submersed tubers, and the nutlets and other plant parts are eaten by birds on occasion; the stems, roots, and tubers of this plant can serve as food for muskrats, porcupine, and beaver. Its starch-rich rhizomes can be utilized by man, and the arrowhead provides shelter and shade for young fish.

Carex: Attractive to marsh birds, wildfowl, shore birds, and song birds, the nutlets are eaten by wildfowl with the plants eaten by upland game birds, beaver, deer, and muskrat. Cyperaceae is generally considered to be one of the most important plant families for wildfowl, and the true sedges usually provide a good forage for cattle and other grazers; however, certain of the species show a higher benefit for this application than other species of this same genus.

Eleocharis: The roots are eaten by muskrat, and these plants provide fair food for wildfowl; the roots and stems of E. acicularis are mostly eaten by birds because of the small nutlets, but the whole plant is utilized in the case of E. palustris. The spike-rushes are not generally used by domestic and other grazing animals because of their inaccessibility in marshy locations and shallow water. E. acicularis forms spawning grounds for certain warm-water fish species, while E. palustris supports insects which provide a food supply for these kinds of fish.

Scirpus: Attractive to marsh and song birds, these plants are often important wildfowl food; geese eat the rootstocks and shoots while the nutlets and some tubers provide a good source of nourishment for ducks. The bulrushes are also eaten by muskrat. Scirpus vegetation is often used for nesting by certain warm-water fish species, and S. acutus and S. validus afford some degree of shelter for the younger pisceans; but S. americanus is of little value in this regard. Most of these spe-

Table 7. Continued (the second of three pages).

cies provide a support vehicle for aquatic insects which in turn act as a food supply for fish, but these same plants have only a slight usage as a fish food in their own right.

Juncus: Eaten by wildfowl and upland game birds, the rushes are also attractive to marsh and song birds with the stem bases and roots sparingly eaten by muskrat. The forage values of the more tender species are considered as fair to good for domestic animals and other grazers, and these plants also form spawning grounds for certain species of warm-water fish. *J. balticus* is described as a fairly useful forage.

Poaceae: Young life forms are eaten by deer, muskrat, beaver, and other wild and domestic animals, although the forage worth varies by grass species and by the particular grazer; for example, aquatic *Glyceria* spp. are heavily grazed by deer, and they are an important duck and muskrat food, while *Beckmannia syzigachne* and *Spartina pectinata* are generally of little import as a source of food for wildfowl. The grasses attract marsh birds, wildfowl, and shore birds, and the grains are principally eaten by such animals; however, the early shoots can sometimes serve as an important source of food for certain types of birds.

Heteranthera: Eaten by ducks and attractive to some other specis of wildfowl, this plant also provides food and shelter for fish.

Potamogeton: With the possible exception of the somewhat tough *P. robbinsii*, often a favorite food of wildfowl with either the whole plant eaten or certain preferable plant parts. The pondweeds are a staple food for ducks, and all of the species are consumed by these birds, including *P. robbinsii*; however, the nutlets and tubers of *P. pectinatus* make this plant the most important pondweed for duck nutrition. Attractive to marsh and shore birds and wildfowl, these plants are heavily eaten by muskrat, beaver, and deer. Most species, including *P. foliosus* and *P. richardsonii*, provide good cover for fish, and *P. pectinatus* is particularly noteworthy in this regard for young trout and other small fish, while *P. robbinsii* is particularly suitable for northern pike. The starch in the tubers and rootstocks of *P. filiformis* and *P. pectinatus* make them valuable as a fish food, and *P. foliosus*, *P. robbinsii*, and *P. richardsonii* are also used as a less palatable source of food by various fish species; furthermore, many of the pondweed associations support rather dense aquatic insect populations, and these invertebrates can also be utilized as foodstuffs by carnivorous higher animals that inhabit or visit the water. Like the Cyperaceae therefore, the pondweeds represent a very important plant family in most aquatic ecosystems.

Sparganium: Providing a good plant cover that attracts marsh birds and wildfowl, the nutlets of *S. eurycarpum* are of good value and are eaten by birds in small quantities, and *S. angustifolium* provides a fair duck food. The bur-reeds are a preferred food of deer with the basal parts of *S. eurycarpum* also heavily utilized by muskrat, but these plants are of no major benefit as a source of edibles and cover for fish.

Table 7. Continued (the third of three pages).

Typha: Acting as shelter for young fish and as spawning grounds for some fish species, these plants support insects which can be used as a source of food for these animals. Cat-tail stands attract marsh birds, wildfowl, and song birds, and they provide fair food for some geese but rarely for ducks. Stocks and roots are an excellent and important food for muskrat, and Typha is also eaten by beaver.

Zanichella: With the nutlets and sometimes the foliage often serving as a good food for wildfowl, the horned pondweed is also a fair food producer for trout.

Apiaceae: Only a few species of this family provide food for wildfowl.

Bidens: Attractive to upland game birds, ducks, and song birds, the fruits of this plant are mostly eaten by the first species while being of a much lesser importance for ducks.

Myriophyllum: Sparingly eaten by muskrat, this plant is a fair duck food with other wildfowl eating the fruits and with a few consuming the foliage; however, water-milfoil can become excessively weedy and thereby unimportant as a food supply. In terms of a water's fish population, Myriophyllum provides shelter and acts as a valuable food provider by supporting many types of insects, and the roots of this plant can be used by some warm-water fish species for nesting.

Hippuris: Seeds and sometimes foliage provide a fair food for wildfowl, including ducks, and the mare's-tail generally harbors small forms of aquatic life that can serve as a food cache for many higher animal species such as fish.

Lamiaceae: Various species of mint are eaten by upland game birds, pintail, green-winged teal, ruffed grouse, and muskrat.

Utricularia: Generally of little or no value as a food for ducks and other forms of wildfowl, and sparingly eaten by muskrat, the bladderwort may provide refuge to small invertebrates that can be used as a source of food by fish and other animals; the plants per se may afford a means of cover for some fish species as well as a means of nourishment for these same animals.

Polygonum: Heavily eaten (foliage) by deer in the summer, this plant is little utilized by such ungulates during the other seasons. Smartweed is sparingly eaten by muskrat, but it does provide a good food source and good shelter for fish. The nutlets appear to be the only plant parts consumed by wildfowl and upland game birds, and Polygonum is also used to some extent by shore and song birds where it has a fair rating from the standpoint of nutrition.

Ranunculus: Eaten by upland game birds and wildfowl, the aquatic plants of the buttercup family are typically fair producers of food for trout and certain other fish species.

not found in the Poplar area but are common to Montana have also been included into Table 7 for illustrative purposes and to expand the information base since macrophyte-use data are not available for many of the Poplar's fish and wildlife species. The potential importance of the individual macrophytes in the study area with reference to the animals of the region can then be at least generally judged from the contents of the table. The absence of a plant taxa from the table indicates that no judgements on its wildlife applications were available in the reference sources utilized by Fassett.

NONBIOLOGICAL DATA PRESENTATIONS AND CHARACTERIZATIONS

WATER QUALITY PARAMETERS--DISSOLVED COMPONENTS

Hydrogen Ion Concentrations or pH

Potential Influence of the Cookson Impoundment. The pH readings measured for the water samples collected from the seven stream appraisal sites are summarized in Table 8 for each of the three sampling trips. Several distinct features become evident in this pH data, and one of these pertains to the comparatively low values that were obtained for the upper East Poplar near the international boundary (stations I and II) in relation to the higher pH's of the other sites. In addition, the upper East Poplar pH's were fairly constant through the three sampling dates, ranging between 7.90 and 7.98, and they did not provide any marked evidence amongst themselves of the occurrence of any downstream, seasonal, or diurnal variations as can be observed with the remaining sites.

Such low and constant pH levels are suggestive of a recent water quality influence by the upstream Cookson impoundment since a median summer low flow pH for the East Poplar at the international boundary for the 43 pH measurements that were taken from the stream for this period prior to the closure of Morrison Dam (Klarich, 1978) was found to be distinctively higher at 8.39 than the post-closure readings in Table 8. Thus one minor water quality effect of the Cookson Reservoir appears to be a slight pH depression in the extreme upper part of the East Poplar and about a 2.75-fold enhancement of hydrogen ion concentrations in this reach. Furthermore, the reservoir also tends to dampen the stream's natural pH variations through an upper two or three mile section of the river in Montana.

Direct Biotic Effects and Reference Criteria. The pH depression in the East Poplar that results from the Cookson impoundment is in no way of an adequate magnitude to cause any adverse effects on the aquatic organisms of the river because pH's as low as 6.5 units can be readily tolerated by most freshwater plants and animals (Katz, 1969). From the standpoint of pH, therefore, the Cookson Reservoir does not appear to have a significant or direct impact on the aquatic ortanisms of the upper East Poplar River in spite of the hydrogen ion increases.

The potential for negative pH effects in the Poplar drainage appears to reside primarily at the high end of the pH spectrum as the result of the *in situ* development of excessively low hydrogen ion and high hydroxyl concentrations rather than from the occurrence of excessively high levels of the proton case. In addition, this manifestation of high pH's in the drainage is most likely a natural phenomenon that is at least partly related

Table 8. Results obtained from the pH, dissolved oxygen, specific conductance, turbidity, and light transmittance analyses of water samples collected during this study from the seven stream appraisal sites in the Poplar River drainage of Montana. An explanation of the table abbreviations is presented in the footnotes.

Sampling				DO				Percent Light Transmission*									
								at 450 millimicrons					at 650 millimicrons				
Station	Date	Time	pH	mg/l	%Sat.	SC	Turb	2 cm	1 ft	2 ft	3 ft	4 ft	2 cm	1 ft	2 ft	3 ft	4 ft
I-EP	7/30/80	1145	7.98	--	--	1400	0.8	97.7	70.1	49.2	34.5	24.2	99.1	87.1	75.9	66.1	57.6
II-EP	7/31/80	0918	7.90	--	--	1365	0.6	97.0	62.9	39.5	24.8	15.6	99.0	85.8	73.6	63.2	54.2
III-EP	7/30/80	1614	8.60	--	--	1355	0.6	96.7	60.0	36.0	21.6	12.9	99.0	85.8	73.6	63.2	54.2
IV-EP	7/31/80	1418	9.50	--	--	1140	1.1	89.2	17.5	3.1	0.5	0.09	98.0	73.5	54.0	39.7	29.2
V-EP	8/01/80	1218	9.35	--	--	1550	5.8	89.2	17.5	3.1	0.5	0.09	94.2	40.2	16.2	6.5	2.6
VI-MP	7/31/80	1602	8.48	--	--	1435	14.	87.2	12.4	1.5	0.2	0.02	88.8	16.4	2.7	0.4	0.07
VII-MF	8/01/80	0933	8.93	--	--	1698	16.	76.0	1.5	0.02	<.01	<.01	82.8	4.9	0.2	0.01	<.01
I-EP	8/28/80	1435	7.92	10.35	120	1400	1.5	96.8	60.9	37.1	22.6	13.8	99.0	85.8	73.6	63.2	54.2
II-EP	8/27/80	0948	7.97	8.43	87	1385	0.9	97.1	63.9	40.8	26.0	16.6	99.2	88.5	78.3	69.3	61.3
III-EP	8/27/80	1408	8.30	12.87	144	1375	1.9	95.4	48.8	23.8	11.6	5.7	98.8	83.2	69.2	57.6	47.9
IV-EP	8/28/80	1635	9.18	14.38	173	1390	2.1	89.8	19.4	3.8	0.7	0.1	97.1	63.9	40.8	26.0	16.6
V-EP	8/28/80	1205	8.89	9.40	103	1435	6.2	88.0	14.3	2.0	0.3	0.04	95.1	46.5	21.6	10.1	4.7
VI-MP	8/27/80	1700	8.30	10.05	119	1305	5.9	92.9	32.6	10.6	3.4	1.1	96.2	55.4	30.7	17.0	9.4
VII-MF	8/28/80	0950	8.98	8.60	93	1545	6.3	78.9	2.7	0.07	<.01	<.01	89.0	16.9	2.9	0.5	0.08
I-EP	9/17/80	1609	7.92	9.71	95	1435	2.8	96.8	60.9	37.1	22.6	13.8	98.2	75.8	57.5	43.6	33.0
II-EP	9/16/80	0903	7.90	9.70	89	1410	2.0	97.2	64.9	42.1	27.3	17.7	99.0	85.8	73.6	63.2	54.2
III-EP	9/16/80	1340	8.22	11.81	114	1400	1.4	97.3	65.9	43.4	28.6	18.9	98.8	83.2	69.2	57.6	47.9
IV-EP	9/17/80	1203	8.72	7.84	77	1470	1.8	92.0	28.1	7.9	2.2	0.6	98.1	74.7	55.7	41.6	31.1
V-EP	9/17/80	0903	8.80	7.90	78	1580	5.8	90.8	23.0	5.3	1.2	0.3	94.1	39.6	15.7	6.2	2.5
VI-MP	9/17/80	1351	8.30	9.76	97	1300	4.7	95.5	49.6	24.6	12.2	6.0	96.8	60.9	37.1	22.6	13.8
VII-MF	9/16/80	1602	9.02	10.70	110	1870	13.	82.0	4.9	0.2	0.01	<.01	86.8	11.6	1.3	0.2	0.02

*Measured percent light transmission of the sample water using a two centimeter cuvette, and the calculated transmission values at one, two, three, and four feet of stream depth.

DO--dissolved oxygen in milligrams per liter and as percent saturation (%Sat.); SC--specific conductance as micromhos per cm at 25C; Turb--turbidity in nephelometric turbidity units; EP--East Poplar stations, MP--main Poplar station, and MF--Middle Fork station.

to the vegetational density of the streams and not directly related to the presence of the Cookson impoundment. Evidence for the possibility of such high pH effects on the aquatic organisms is drawn from a few of the exceptionally high pH values in Table 8 in conjunction with two pH reference criteria that can be summarized as follows: the Environmental Studies Board's (1973) and the Environmental Protection Agency's (1976) pH recommendations of 6.5 to 9.0 units to insure a "moderate level of protection" for "freshwater aquatic life," and the Environmental Studies Board's summer pH recommendation of 7.0 to 9.2 units to insure the maintenance of aquatic plants that are "of greatest value as food for waterfowl."

The pH's that are listed in Table 8 never fall below the lower limits of the ranges recommended by the two federal agencies, although some of the higher pH's in the table do exceed the upper limits. This latter feature then may point to the occurrence of some adverse influences upon the plants and animals that inhabit the appropriate stream reaches. However, such high pH effects, if present, are undoubtedly temporary in nature, and they are probably rather minor in character in terms of their overall intensity.

Indirect Biotic Effects. The main biotic influence of the reduced pH levels stemming from Cookson Reservoir appears to be an indirect one that revolves around a fairly significant enhancement of the East Poplar's free carbon dioxide (CO_2) concentrations through a short stretch of the river immediately below the dam over the pre-impoundment levels of this constituent for the same reach. For example, at a summer pH of 7.95 and a total alkalinity concentration of 500 milligrams of $CaCO_3$ per liter, a free CO_2 concentration of 10.9 milligrams per liter (mg/l) would be present in the water according to the equation of Rainwater and Thatcher (1960), and this CO_2 value is fairly representative of the post-impoundment summer concentrations that might be found in the upper East Poplar. In contrast, a free CO_2 concentration of 3.9 mg/l was observed to be generally typical for the stream before the closure of Morrison Dam. Such an increase in this particular parameter prescribes a positive effect from the standpoint of the aquatic macrophytes since it provides an added amount of dissolved free CO_2 which serves as a par excellence carbon souce for aquatic plant photosynthesis.

As a result of these chemical features, one of the water quality effects of the Cookson Reservoir is found in an alteration of the below dam pH-carbon species relationships, and this change could produce some form of elevation in primary production through the upper East Poplar via an increase in the water's free CO_2 concentrations. However, this CO_2 enhancement is rather rapidly dissipated downstream as the CO_2 is gradually lost to the atmosphere and utilized photosynthetically by the sequence of macrophyte communities that occur along the river, and this excess CO_2 has been largely purged by the time the water reaches station IV on the stream (Figure 1). The exact degree of any production increases that could result from the CO_2 enrichment of the upper East Poplar is unknown, but it is probably not too extensive in view of the high carbon source availabilities in the river. Of course, any production elevations of this kind should be viewed as detrimental if they happen to cause additional macrophyte growths that could lead to a deterioration of the habitat values of the stream.

But for the most part, the effects of pH on the biota of the drainage appear to be relatively minor overall as expressed by the values in Table 8. However, these data are quite limited, and they only describe the pH conditions of the streams for the daytime hours during the summer season. Negative pH effects that could develop during the nighttime hours and during the other seasons cannot be assessed by the sets of numbers in Table 8. As a result, diurnal and further seasonal analyses of particular water quality parameters such as pH, alkalinity, CO_2, and dissolved oxygen at a number of points within the drainage seem to be an important and essential avenue to pursue in terms of any future research in the Poplar basin. And in conjunction with this kind of work, stream production levels can be estimated from the data that would be obtained from these diurnal evaluations.

Indicator of Stream Production. Another distinctive aspect of the pH data in Table 8 pertains to the marked increases in this variable that were obtained from the border conditions in the upper East Poplar to the distinctively high values that are seen in the lower reaches of the river. The development of these pH features was probably related to a high photosynthetic activity through most of the East Poplar waters; that is, the daytime utilization of CO_2 and bicarbonate via the photosynthetic processes of dense and submersant aquatic weed beds could significantly raise the pH levels of a stream, and an extensive photosynthetic use of bicarbonate as a carbon source can elevate pH to the extremely high levels in excess of 9.0 units as observed at some of the study stations.

The feasibility of an extensive bicarbonate utilization in the East Poplar is confirmed by the fact that several of the aquatic plants identified in the river, including Chara and many of the Potamogeton species, are well known for their ability to abstract lime from a water for photosynthetic purposes, and this results in a biogenetic precipitation of marl with a general softening effect on the water system through a removal of calcium and magnesium ions (Fassett, 1969). Thus the high pH values that are achieved in the East Poplar indicate that this river has relatively high levels of primary production, and on this basis, relatively dense stands of submersant macrophytic vegetation might be anticipated for the stream.

For the most part, the physical and water quality features of the upper East Poplar reaches are conducive to the attainment of high levels of productivity and the development of extensive macrophyte growths. This success basically revolves around the occurrence of several factors as follows: the ponded nature of the stream with the appropriate depth, current velocity, and substrate characteristics; the lack of extensive runoff scouring because of the development of the upstream impoundment; the availability of high concentrations of suitable carbon sources for photosynthesis; and the general clarity and warm summer temperature of the waters. The latter two factors will be considered in more detail later. Furthermore, the extremely critical nitrogen and phosphorous nutrient concentrations of the upper part of the river are somewhat suggestive of eutrophic conditions as has been noted by Klarich (1978).

At the southern end of the study area, however, a decline in pH did become evident as shown in Table 8 when going into the extreme lower East Poplar and the upper mainstem near Scobey, and this observation suggests that a downstream drop in stream production does occur in the river along with an accompanying reduction in the system's plant biomass levels through the lower reaches. One possible explanation for such a downstream decrease in plant biomass references the nitrogen and phosphorous levels of the lower segments which appear to be less conducive to the formation of extensive macrophyte growths, principally because of a nitrogen limitation, than is the case for the upstream sections near the international border (Klarich, 1978). Also, runoff scouring could again develop some importance in terms of controlling plant growth in the stream segments that are progessively further removed from the Morrison Dam. For whatever reasons, the East Poplar River does demonstrate a wise range of primary production levels through its various reaches.

Seasonal Variations. A final pattern that is obvious in the pH data of Table 8 relates to the seasonal decrease of this variable that is seen at most of the stations, and the 9.50 to 9.18 to 8.72, mid-summer to late summer-early autumn pH sequence that was obtained at station IV provides the best example of such a decline. This type of seasonal pH variation generally supports the conclusion that the different pH levels that were shown by the stations were largely prescribed by the photosynthetic activities of the particular aquatic macrophyte communities of the stream locations. The rationale for involving this type of relationship is summarized below.

In the first place, the study data suggests that the inter-station pH discrepancies that were seen on each of the sampling trips were primarily dependent upon the differences in plant biomass and amounts of photosynthetic tissue between sites. Secondly, the first trip to last trip pH declines at a site corresponded to the general deterioration of the macrophyte communities that was observed when making the final set of transect runs at the stations in mid-September. This morphological and physiological degradation relates to the development of the senescent stage of the plants' life cycle as they move into the cold weather season. A decline in the photosynthetic activities of the macrophytes would be expected to accompany the onset of senescence, and this would be reflected by a reduction in stream production, a reduced utilization of the water's carbon sources, and a reduced influence of the plants on the pH characteristics of the stream, i.e., a lessening of the photosynthetically induced pH elevations during the daytime hours. This latter aspect then correlates with the pH data that were collected as a result of this project. Thus in the fall, the streams' pH values were observed to be lower and closer to a pH that would be descriptive of the water sans the influence of any weed beds.

The actual loss of some macrophyte biomass could have occurred in the streams when going into the senescent plant stage, and this loss, like the case of a physiological alteration, would also produce lower levels of stream production and a reduced biotic effect on the water's pH levels. However, the occurrence of distinct plant biomass losses between sampling trips did not become evident when conducting the field work, although marked declines in macrophyte abundance do eventually occur in the streams with the advent of the cold weather season.

To extend this sequence of events for a few added months, the aquatic plants, at the start of the winter season and ice-over conditions, completely die back to their overwintering organs with the plants nonphotosynthetic during this period. The pH characteristics of the streams at this time are then biologically dependent largely upon the respiratory activities of the substrate microorganisms, and the levels of pH tend to drop because of a net CO_2 accrual to the water. The pH's are often observed to be generally lower for the winter season, and low winter pH's in the vicinity of 7.50 to 8.00 units have been recorded for the upper Poplar River drainage by other researchers (Klarich, 1978).

As an accessory note, winter pH values were found to be generally lower in the upper East Poplar in the vicinity of the international boundary (near 7.50 units) than they were in the lower East Poplar near Scobey and at the other sampling stations of the upper drainage (closer to 8.00 units), and this feature could be related to the higher biomass levels of the died-back macrophytes that would be available in the upper reach for the decay process and microbe respiration over the other stream segments. For this reason, water CO_2 accrual would be greater during the winter in the upper East Poplar which would produce the lower pH values of this particular river section. In the main, therefore, the seasonal variations of pH in the East Poplar River closely follow the pattern that would be expected with reference to the life cycle characteristics of the higher aquatic plants. In terms of the inter-station pH differences, the macrophyte data that have been collected during this study will reveal whether such differences were in fact due to variations in aquatic plant biomass levels among the different appraisal sites.

Middle Fork Comparisons. The pH values of the East Poplar River are suggestive of relatively high macrophyte biomass levels in the middle segments of the stream with somewhat lower plant abundances near the international border and in the lower part of the river near Scobey and with a marked biomass decline into the Poplar River mainstem. The high pH's of the Middle Fork also point to the occurrence of a relatively high macrophyte abundance, but since the mid-summer pH's of this central stream tended to be lower than those of the middle East Poplar, the plant biomass of the Middle Fork would be expected to be somewhat lower than those of the more eastern reach. However, such inter-stream pH comparisons also indicate that the Middle Fork biomass levels should be greater than the plant abundances of the main Poplar River. The actuality of these abundance relationships will be reviewed in a subsequent section of this report.

As a final observation, the seasonal pattern of pH change was found to be quite different in the Middle Fork versus the East Poplar River as illustrated in Table 8. That is, the East Poplar, except for the border stations that were affected by the Cookson impoundment, showed a fairly distinct decline in pH from the first to the last sampling trip while the Middle Fork demonstrated a very slight increase in this variable through the same time period. This lack of a seasonal pH change in the middle river would suggest that some factor apart from the aquatic biota could have been influencing the pH status of the stream with this factor causing a deadening of the biological and seasonally related pH variations that might be expected for the water. But representing a second option, the aquatic plants of the Middle Fork could have started their approach to the senescent stage of their life cycle at a later time than those of the East Fork so that the last sampling trip would have been made at too early a date to pick up the biotically related pH declines that would be anticipated for the late summer--early fall period. As a further item in this line of reasoning, the biotic or abiotic trigger(s) that would act to initiate the onset of plant senescence could have been expressed at a later date in the Middle Fork than in its sister stream.

Whatever the case, the exact cause of the differences between the seasonal pH patterns of the East and Middle Forks is unknown and cannot be readily established from the data that are available to this present study. Furthermore, the likelihood of a delayed plant senescence in the Middle Fork is also not known, although this prospect is not totally unreasonable as an explanation for the above described inter-station pH discrepancies. As a general qualitative observation, the plants in the Middle Fork did appear to be more viable during the last sampling trip than those in the East Poplar, but no concrete evidence is at hand by which to confirm the actuality of such potential botanical differences between the two streams.

Oxygen Concentrations: Intra-Study Data

General Comparisons and Stream Production Relationships. The results from the dissolved oxygen (DO) analyses of the water samples that were collected from the seven stream appraisal sites during the late August and mid-September sampling trips of this macrophyte survey are summarized in Table 8 in the form of absolute concentrations (mg/l) and in the form of percent saturation values. Like the case for pH, fairly distinct seasonal and diurnal patterns of inter-sample variation are evident in these numbers. However, the inter-station differences are not particularly consistent between sampling dates because of the missing values for the initial site visitations and because of a masking by the diurnal and seasonably related DO changes. Nonetheless, the particular relationships among the Table 8 oxygen data do suggest that the concentrational differences of this parameter among the samples were at least partly related to the biological activities of the macrophyte communities within the streams, and this DO data, thereby, generally confirms the conclusions that were derived from the pH values.

In the first case, the extremely high mid-summer and afternoon DO concentrations and percent saturation (%Sat) numbers that were obtained from some of the East Poplar sites (e.g., stations II and IV) point to a high photosynthetic activity and a marked accrual of oxygen by the water via this physiological process. This, in turn, is suggestive of a high stream production and high plant biomass levels in the middle East Poplar as was described by the pH data, and somewhat lower plant abundance levels are indicated for the upper East Poplar and the Poplar mainstem.

In the second case, the distinctive drop in %Sat values from the late August to the mid-September period points to the occurrence of a decline in stream productivity through this time frame in accordance with the development of plant senescence and the manifestation of reduced photosynthetic rates that are seen during the fall season as noted earlier. In addition, the inter-sample DO variations for each of the collection trips became less distinct through this same period of time, and this feature is also indicative of a reduced water quality influence of the macrophytes when moving into the autumn period. As a result, the minimum daytime DO values tended to be slightly lower while the maximum daytime DO values tended to be considerably lower in the fall versus the summer months, and these relationships would be expected with an autumn reduction in photosynthetic activity.

In the main, therefore, both the pH and the DO data generally correspond in making judgements that describe the biological characteristics of the study area streams. Unfortunately, DO data which would further confirm this correspondence and enhance the biotic descriptions are not available for the first field trip to the Poplar drainage when photosynthetic activities in the streams would be expected to be particularly distinct as revealed by the pH values. Extremely high midday %Sat values would undoubtedly have been also obtained from some of these first trip DO samples if they had been collected from the streams.

Middle Fork Comparisons. With respect to the Poplar Middle Fork, the DO data from this stream are not very useful for developing any kind of relative stream production judgements because the times of sample collection on the site visitations were not appropriate for making the requisite comparisons. In general, the DO levels of the Middle Fork did not prove to be very distinctive in any fashion, and they fell within the range of values that were obtained from the East Poplar and the upper reach of the main Poplar River.

Diurnal and Seasonal Variations. The most obvious type of pattern of DO change in the Poplar streams is found in a diurnal cycle that is best reflected by the %Sat numbers of Table 8. To a significant degree, the values of this variable were observed to be lower for the samples that were obtained during the earlier morning hours than they were for the water collections that were secured during the afternoon, and intermediate %Sat values were most typically obtained from the mid-afternoon samples with the highest %Sat levels obtained during the latter part of the day. These features can be illustrated quantitatively by first converting the %Sat data from each of the sampling trips to a relative scale with reference to the mean value for that set in order to eliminate the effect of the seasonally related DO alterations. The adjusted %Sat numbers from the two sets can then be combined and separated on the basis of the time of collection which produces the following average results for three distinct periods of the day: morning (0900 to 1000), relative %Sat = 0.82 with four observations; mid-afternoon (1200 or noon to 1500), relative %Sat = 1.02 with six observations; and late afternoon (1600 to 1700), relative %Sat = 1.15 with four observations.

As suggested by the above refined %Sat data, a fairly marked increase in relative DO concentrations did occur in the streams through the daytime period which was significant statistically at 5% with a one-way analysis of variance ($F^{2}_{11} = 4.98$). The general distinctiveness and the consistency of this diurnal change in DO also points to the occurrence of high plant biomass levels within the Poplar streams.

As a related observation, the range between the morning minimum and the afternoon maximum absolute DO concentrations was somewhat greater during the mid-August sampling trip with a 1.71-fold difference than it was during the later and final field foray which provided a 1.51-fold difference between the minimum and maximum DO numbers. This seasonal change in the afternoon/morning, maximum/minimum DO ratio was obfuscated to some extent by a small decline in the minimum morning DO value from the second to the third trip (a decrease of about 0.5 mg/l), but the ratio difference between trips was greatly enhanced by a rather marked decline in the afternoon maximum value through this same inter-monthly period (a decrease of about 2.5 mg/l). All of these diurnal and seasonal DO variations can be referenced to a biological explanation as is described below.

The low morning DO levels and %Sat values that were observed in the early day samples were due to a respiratory use of oxygen through nonphotosynthetic nighttime hours by the plants and the animals of the streams which reduced its absolute concentrations. Subsequently, the gradual increase in DO concentrations through the daytime period to a maximum value in the afternoon, which replenished the nighttime respiratory losses, corresponded to a sequential and net DO accrual in the water as a result of plant photosynthesis. In contrast to the afternoon hours, the morning DO concentrations were comparatively low in the water because an inadequate light exposure period had been available to the plants prior to the time of collection to allow for a suitable photosynthetic production of oxygen to totally replenish the earlier uptake by respiration.

As a further explanation along these lines, afternoon DO levels were lower in mid-September than in late August because of the reduced photosynthetic rates that occur later in the year in conjunction with the onset of macrophyte senescence. In addition, the minimum morning DO levels were lower in mid-September than in late August for this same basic reason. That is, total DO accrual at the rates of photosynthesis that occurred during the early fall was less efficient than the summer photosynthetic rates in balancing nighttime respiratory losses at the respective levels of oxygen consumption, and this would produce a slightly greater DO depression in the morning minimum of the early fall season over that of the summer period. Furthermore, this early fall and morning DO minimum could have been greater than what was observed except for the fact that plant senescence can also retard respiratory activities, and this would produce a lower demand on the reduced oxygen concentrations that were made available from the daytime photosynthesis of the mid-September period than would be the case for the non-senescent months.

In essence, therefore, the DO shifts that were observed in the streams from one sampling date to the next sampling date were produced at least in part by a change in the photosynthetic-respiratory relationships and rates of the streams' aquatic plant communities, and the inter-sample variations of DO from the Poplar streams closely corresponded to the differences that might be expected as a result of the biologically related diurnal and seasonal cycles of the waters. The water's physical loss and gain of oxygen to and from the atmosphere and the seasonal temperature changes of the streams provided a couple of the potential complicating factors to these biological manifestations, and the temperature feature will be considered in a later section of this report.

General Reference Criterion. Dissolved oxygen is one of the most important of the water quality parameters to evaluate from the standpoint of the maintenance of aquatic life, particularly in relation to a water's fishery, and consistently low DO concentrations can reduce the viability and vigor of many submersant plant and totally aquatic animal species. Also, extremely low DO levels can be lethal to most members of the lotic and lentic biota. In response to these features, the Environmental Protection Agency (1976) made a recommendation of 5.0 mg DO/l as the ". . . minimum concentration of dissolved oxygen to maintain good fish populations . . . ." In relation to this criterion, this agency further stated ". . . that as long as dissolved oxygen concentrations remain entirely satisfactory for fish (i.e., above 5.0 mg/l), no material impairment of the food resources for fish (i.e., aquatic insects and other animals and plants on which the fish feed) ascribable to a dissolved oxygen insufficiency will occur." Although numerous criticisms have been directed the the Environmental Protection Agency's single number DO criterion, as summarized by Thurston, et al (1979), this 5.0 mg/l value seems to be adequate as a general reference point for evaluating the DO data that were collected as apart of this macrophyte survey and as a part of other inventories in the Poplar drainage.

Potential Influence of the Cookson Impoundment and General Biotic Effects. In relation to the absolute DO concentrations in Table 8, none of the mid-summer to early fall daylight DO levels obtained from the Poplar streams came anywhere close to falling below the 5.0 mg/l reference value, and this suggests that the streams' oxygen levels for this particular monthly-daytime combination should be more than sufficient to sustain aquatic life. Such a conclusion can also be directed to the East Poplar at the international boundary which indicates that the Cookson impoundment does not have an adverse effect on the day-time DO relationships of the river during the summer season. Furthermore, the DO and %Sat levels that were obtained in this study for the East Poplar border site were generally similar to the magnitudes of these parameters that were recorded for the summer period from the same stream location prior to the closure of Morrison Dam.

For example, mean and median DO values for eighteen pre-impoundment samples equalled 9.1 and 9.4 mg/l with %Sat numbers in the vicinity of 96% (Klarich, 1978), and these statistics are not too unlike those that were collected from the upper East Poplar during this more recent investigation. These comparisons also point to the absence of any marked influence from Cookson Reservoir in altering the DO characteristics of the East Poplar River during the warm weather months.

Oxygen Concentrations: Extra-Study Data

Summer Nighttime Biotic Effects. Like the case for pH, nighttime DO concentrations during the summer and the DO levels of the streams during the other seasons of the year as well as the possible effects of the Cookson impoundment on this parameter during the non-summer periods cannot be directly evaluated in terms of any adverse biotic effects from the results of this particular study. However, Stewart (1979) did obtain nighttime DO readings from several locations on the Poplar drainage streams for the summer season that can be reviewed in conjunction with the data from this macrophyte work. He collected the DO samples from mid-July to mid-August at a time (between 0400 and 0800 hours) when the oxygen depressions should be most pronounced as a result of the evening to early morning respiratory activities of the water's aquatic biota.

Stewart (1979) found that the DO concentrations of these collections were consistently above the 5.0 mg/l criterion for the West Fork, Middle Fork, Poplar mainstem, lower East Poplar, and the extreme upper East Poplar stations in Montana with a minimum value for these stream locations equal to the reference number and with a mean concentration of 7.1 mg/l for the 66 samples. In contrast, DO levels commonly below the reference criterion were obtained from a middle East Poplar sampling site with 64% of the samples from this location showing this condition in the range of 2.8 to 4.6 mg/l and with an average of 4.8 mg/l for the eleven collections. Thus some oxygen stresss might be anticipated for the middle segment of the eastern fork, and this corresponds to the high rate of respiratory oxygen utilization that can be expected for the dark hours from the luxurious submersant weed beds that have been observed in this part of the drainage. Conversely, nighttime oxygen use by macrophyte communities would be much lower in the other stream segments because of their less dense plant growths, and this would result in the less distinct early morning DO depressions that were obtained in these other stream reaches.

As suggested by Stewart (1979), therefore, ". . . only values at the middle station were sufficiently low to cause stress in walleye and northern pike. With this exception, summer dissolved oxygen in the Poplar River drainage does not appear to be a problem for fish." According to the reasoning expounded by the Environmental Protection Agency, this same conclusion might then also be directed to the other biota of the streams. As a result, the Cookson impoundment in itself does not appear to have a significant negative effect on the DO characteristics of the East Poplar River during the nighttime hours of the summer season.

Cold Weather Oxygen Depressions. In addition to the summer nighttime DO reductions that were described by Stewart (1979) for the middle East Poplar River, cold weather depressions of this variable have also been identified at various points in the Poplar drainage by other sampling projects as summarized by Klarich (1978). Such depressions are best illustrated by the median and minimum %Sat values of the different stream collection sites for samples obtained during the November to February winter season. These statistics can be listed as follows with the corresponding absolute DO concentrations included in the parentheses: upper East Poplar at the international boundary (IB)--47% (5.5 mg/l) and 6% (0.8 mg/l); lower East Poplar--60% (8.0 mg/l) and 39% (5.2 mg/l); upper Middle Fork at the IB--82% (10.6 mg/l) and 78% (8.4 mg/l); lower Middle Fork--71% (9.5 mg/l) and 60% (8.0 mg/l); upper West Fork at the IB--34% (6.2 mg/l) and 16% (2.2 mg/l); lower West Fork--71% (9.5 mg/l) and 54% (7.2 mg/l); upper main Poplar--74% (9.9 mg/l) and 63% (8.4 mg/l); lower main Poplar--90% (12.2 mg/l) and 68% (9.2 mg/l).

As indicated by the above listing, the occurrences of winter oxygen depressions in the Poplar region are reflected by the relatively low median %Sat values that were typically observed to be below 90% for this reason and by the low minimum %Sat numbers that dropped below 70% at most of the stations; furthermore, extremely low minimum %Sat values below 30% were obtained from a few of the samples. Such DO reductions were most consistent and pronounced in the upper East Poplar and least distinct in the Poplar River mainstem and in some of the other stream reaches.

A similar pattern of winter DO depressions has also been obtained by the United States Geological Survey (1975-1979) for years more recent than the Klarich tabulations (i.e., water years 1978 and 1979) with the main Poplar having median and minimum %Sat values on the order of 76% (9.9 mg/l) and 55% (7.4 mg/l) but with the upper East Poplar at the IB having much lower median and minimum numbers of 39% (5.1 mg/l) and 17% (2.3 mg/l) for the cold weather months of 1977 and 1978. However, adequate DO data are not yet on hand by which to determine if the presence of the Cookson Reservoir might contribute to the winter DO reductions of the upper river reach. An influence of this kind that might emanate from such an impoundment is not totally unfeasible from a water quality point of view. For the remaining Poplar drainage stations, the median USGS %Sat values for the winter months varied between 66% and 91% (8.8 and 11.6 mg/l) for water years 1978 and 1979 with the minimums typically in the range 56% to 74% (10.0 to 11.6 mg/l), although distinctively low minimums below 30% (below 3.5 mg/l) were recorded for the lower West Fork and the lower Middle Fork stations during the winters of these same two years.

The winter DO depressions of the Poplar drainage streams are probably caused at least in part by a gradual decay of the dead macrophyte tissue that is leftover from the previous summer's growth with a respiratory utilization of the water's oxygen reserve by the decay microorganisms. Winter oxygen reductions, thereby, would be expected to be more marked in parts of the East Poplar than in the other sampled basin reaches as has been noted above because of the denser macrophyte stands that occur in this eastern river in contrast to the less prolific aquatic plant communities that are found in the main Poplar and the other basin streams. Such depressions are no doubt accentuated during the winter by the absence of a significant photosynthetic replenishment of oxygen during this season, and with the occurrence of ice-over, this problem is further compounded by a restriction of atmospheric oxygen exchange. Thus, the lowering of DO levels is probably most pronounced in the more macrophyte-rich reaches during the more severe winters of the basin when ice development is particularly distinct on the streams.

A requisite avenue of future water quality-biotic research in the Poplar region appears to reside in an extensive winter DO sampling program that should be undertaken on a diurnal basis to further document the extent and degree of the cold weather oxygen depressions in the study streams. Attention should be particularly focused upon the unsampled segments, and sampling efforts should be definitely directed to the middle East Poplar which has demonstrated extremely dense macrophyte growths and for which no winter DO data are yet on hand for review.

Cold Weather Biotic Effects. With respect to the absolute winter DO concentrations, the fact that the median levels of the Poplar streams were always above the 5.0 mg/l reference criterion during the winter season indicates that adequate oxygen is available through most of the cold weather period to support the aquatic biota. However, the occasional observation of fairly low minimum DO values during the November-February period that were well below 5.0 mg/l and in the range of 0.8 to 3.2 mg/l at some of the stations suggests that the development of reduced levels of this variable can have adverse effects on the aquatic biota at some times during the winter months, and this occurrence appears to be most distinct in the upper and middle segments of the East Poplar River. These negative biota effects are most likely to be seen in the streams' fauna rather than the aquatic plant communities since the Poplar's macrophytes undergo senescence, eventually die-back, and then survive the cold weather months in the form of dormant over-wintering organs such as turions, rhizomes, tubers, seeds, and so on.

In any event, the potential is present in the Poplar basin for the development of oxygen-related fish kills and other faunal deaths during the winter period, and the likelihood of this happening is related to the severity of the winter season and the degree of ice-over and to the magnitude of the summer's macrophyte growths in any particular stream segment. That is, extensive fish kills are least likely in the Poplar mainstem and most likely in the middle and upper East Poplar with the other drainage reaches falling into an intermediate category between these two basin extremes. At the minimum, the extreme cold weather oxygen depressions probably cause some level of physiological stress and some temporary and occasional fish and other faunal migrations from the affected segments with these movements being most prevalent during the harder winter months.

Total Ionic Concentrations or Specific Conductance

Potential Influence of the Cookson Impoundment and General Biotic Effects.

One of the major water quality impact concerns directed to the Coronach power generation development revolves around the elevation of stream salinity in the East Poplar and downstream in the main river because of the natural and forced evaporation of water from Cookson Reservoir. A 50% concentration of dissolved solids (DS) at the United States-Canadian border has been projected for the upper East Poplar as a result of the reservoir (Surface Water-Quality Committee, 1978), and this action would increase the salinity of this northern reach to about 1125 mg/l as DS or to about 1700 umhos as specific conductance from the normal summer levels on the order of 800 mg/l and 1200 umhos. However, the major influence of this salinity enhancement will be felt in a general degradation of various offstream water uses such as irrigation and domestic supply and not in a deterioration of the instream biotic features since neither the pre-impoundment or the projected post-impoundment levels of DS in the drainage streams would be expected to have any adverse influences on the aquatic biota, and such a listing would include the macrophytes, algae, fish, and the macroinvertebrates that might be found within the streams (Tennant and Loch, 1979).

The concentrating action of Cookson Reservoir is expected to occur over a period of several years before a maximum increase in salinity is achieved, and the short-term salinity enhancement of the impoundment was observed to be relatively small during the summer that the field work of this macrophyte study was completed a short time after the closure of Morrison Dam. For example, Klarich (1978) found the median pre-impoundment salinity level of the East Poplar for the summer season to equal 1245 umhos as specific conductance at the international border station, and this median value is only slightly lower than the early post-impoundment specific conductances that were obtained in this recent inventory for the same stream location (1400 to 1435 umhos). This represents a rather minor 18% increase in salinity over normal levels versus the maximum 50% elevation that was calculated for the system. Thus, the major salinity enhancement that was projected for the reservoir had not yet been manifested during the warm weather months of 1980.

As indicated in Table 8, one distinctive influence of the reservoir resides in a summer dampening of the natural monthly oscillations of salinity in the upper East Poplar since inter-sample specific conductance variations at the upper three stations on the river from sampling date to sampling date were quite small in averaging only 1.6% to 2.2% of the station maximums. In contrast, inter-sample differences were somewhat greater downstream in the lower East Poplar (6.2%), in the upper main river (7.4%), and in the Middle Fork (11.9%) where the impoundment would have a lesser effect or no effect of this kind.

Seasonal and Inter-Station Variations and Downstream Trends. Of the Poplar stations that were sampled during this macrophyte survey, salinity levels evaluated as specific conductance (SC) were found to be consistently higher in the Middle Fork samples than in the waters collected from the other drainage locations. In terms of the East Poplar sampling sites, SC tended to decrease slightly through the upper three or four stations with a sharp increase then occurring in this variable through the middle and lower segments of the stream so that an overall elevation in salinity was registered from the international border to the Scobey site. This downstream increase in East Poplar salinity has also been observed in other water quality surveys of the region (Klarich, 1978) as has the drop in SC that develops from the lower East Poplar station to the station on the upper mainstem as is shown in Table 8. This lower East Poplar to upper mainstem decline in salinity is somewhat unique in that it occurs across the confluence of the higher DS Middle Fork water (Figure 1) whereby a greater level of SC might be anticipated for the upper part of the main river than in the lower segment of the eastern fork. The absence of this expected increase in salinity from station V to station VI suggests that waters having relatively low DS concentrations must be entering the system from some source through this same lower East Poplar to upper mainstem reach. However, all of these inter-station salinity variations did not occur at adequate levels to differently effect the biota of one stream segment over another in a negative fashion.

Seasonally related changes in stream salinity were not totally consistent among the three site visitations to the study area stations, but in general, the East Poplar and the Middle Fork demonstrated an overall increase in SC from the first to the last sampling trips while the main Poplar showed a small decline. But these slight monthly differences in salinity were again inadequate to significantly alter the potential biotic effects of this variable which have been described as essentially nonexistent at the salinity levels of the streams.

WATER QUALITY PARAMETERS--NON-CHEMICAL COMPONENTS

Turbidity Levels

General Biotic Effects. As described previously, turbidity is an important parameter to consider in the application of water quality surveys because it provides a basic and easily assessed indicator of two stream conditions that can have adverse effects on the aquatic biota. In the first case, turbidity affords a means of generally evaluating the possible restriction of light transmittance through a column of water where the higher turbidity values point to progressively lower degrees of light penetration to the deeper depths. Extremely low levels of light transmittance at a particular stream depth, in turn, are suggestive of a potential reduction in aquatic plant growth and establishment at that stream location as a result of an inadequate light availability to "fire" the photosynthetic process.

As a second factor, turbidity also affords an indirect measure of the suspended sediment concentrations of a water with high turbidity values pointing to high levels of this non-chemical variable. In general, a poor aquatic biota that is low in total numbers, biomass, and diversity is typically associated with streams having high levels of suspended matter. However, the generally low turbidity values that are listed in Table 8 indicate that suspended sediment is probably not a direct biotic problem in the Poplar streams during the warm weather months, although the development of high suspended sediment concentrations during the other seasons of the year, such as spring runoff, could have some temporary and adverse effects of this kind.

The relatively low turbidities that were obtained from the upper East Poplar stations (less than 3.0 NTU) also suggest that light penetration to most of the depths that characterize this stream reach should be more than adequate for plant photosyntheis. But the higher turbidities that were typical for the lower East Poplar, the Middle Fork, and the upper main Poplar River (between 4.6 and 17 NTU) are indicative of the potential occurrence of some light restrictions at the deeper depths of these river segments. The extent of these light reductions can be evaluated more completely by using the percent light transmission data in Table 8 as will be discussed in a later section of this report.

Potential Influence of the Cookson Impoundment. One distinctive feature of the turbidity data in Table 8 pertains to the comparatively low values of this variable in the upper segment of the East Poplar River (stations I to III) with these sampling stations located only a short distance below the Morrison Dam. Such low turbidities stand in contrast to the consistently higher values that were obtained from the Middle Fork appraisal site (station VII) which is unaffected by the Cookson Reservoir. This relationship suggests that the impoundment acts as a sediment trap to distinctively reduce stream turbidities in the East Poplar for a short distance below the dam outfall. But as the water moves further away from the dam into the lower East Poplar reach (station V) and into the upper main Poplar (station VI), it begins to accrue some additional suspended materials, and this loading is reflected in the higher turbidity levels of these downstream locations.

The effect of the Cookson Reservoir as a sediment-trapping vehicle can be further confirmed by comparing the post-impoundment East Poplar-border turbidity data in Table 8 to the summer pre-impoundment values of this variable that have been summarized by Klarich (1978) for the same sampling site. Klarich calculated mean and median warm weather turbidities of 8.1 JTU and 4.6 JTU respectively for the 39 water collections that were made at the border station before the closure of the dam. The higher turbidity values from the pre-impoundment over the post-impoundment samples also point to a significant sediment containment by the Cookson Reservoir. Furthermore, this effect appears to be carried downstream to some extent into the lower East Poplar and the upper mainstem since higher pre-impoundment summer turbidities over those in Table 8 were also obtained from these two stream locations as follows: East Poplar near Scobey--mean and median of 29.4 JTU and 30 JTU for five samples; upper main Poplar--21.3 JTU and 16 JTU for seven samples.

This "cleansing" action of the reservoir is beneficial from the standpoint of the macrophyte communities by enhancing light transmittance and photosynthetic capacities and by retarding the direct and adverse biotic influences of the suspended materials. However, this effect can also be viewed as non-beneficial in relation to the basin's wildlife if the accelerated macrophyte growths that could occur from such post-closure conditions should actually act to degrade the habitat requirements of these different animals.

Light Transmittance Levels

Depth Considerations. With reference to the percent light transmission data in Table 8, the two centimeter values at the 450 and 650 millimicron wavelengths represent the transmissions that were actually measured for a water sample with the spectrophotometer using a two centimeter cuvette. The one, two, three, and four foot percentages denote the corresponding transmission values that were calculated for a representative range of depths that are characteristic of the Poplar drainage streams. The two centimeter readings, in turn, are indicative of the light transmissions that occurred very close to the surface of the water.

The transmission calculations for the one to four foot levels were made on the basis of the Beer-Lambert Law (Reid, 1961) which states that the light restriction (absorbance) for any particular extinction coefficient is directly proportional to the length of the light path when the concentrations of the impeding materials are held constant. These relationships can be applied to each of the Poplar water samples, and the length of the light path, as the only variable, is then equatable to the depth of the stream. Absorbance (A) and transmittance (T) are also mathematically related so that the two expressions can be easily converted from one to the other, i.e., $A = \log (1/T)$.

In essence, therefore, as the length of the light path increases, i.e., as the depth of a stream becomes greater, the amount of impeding substances within the path of light through the water also becomes greater which enhances total absorbance, and light transmittance thereby declines when moving to the greater depths with lesser amounts of light penetrating to the deeper waters. This feature is illustrated in Table 8 where percent transmissions are shown to consistently decline to the deeper points of a stream with respect to all of the drainage samples. Some of the declines in transmission at the deeper depths were observed to be more pronounced than others because of the greater amounts of quenching materials in the water at some of the stream locations as described by their higher turbidity values. In general, rather distinct light-quenching capabilities are evident in all waters even when they possess rather low turbidity levels (Reid, 1961), and this feature is aptly illustrated in Table 8 for the Poplar drainage streams.

Inter-Variable and Inter-Station Comparisons. In addition to the depth-related changes in transmission, this parameter also typically varied among the samples at any one of the evaluated depths, and these variations were due to the inter-station differences in the concentrations of the light absorbing or reflecting substances in the water which are partly related to the suspended sediment levels of the streams. As a result, turbidity which is also related to suspended sediment, and the surface percent transmissions at each of the two wavelengths demonstrated strong inverse relationships across the samples which can be described through the calculation of rank correlation coefficients (r_s) (Hoel, 1966) as follows: $r_s = -.775$ for turbidity and percent transmission at 450 mu, and $r_s = -.902$ for turbidity and percent transmission at 650 mu. Both of these coefficients are statistically significant at much less than 1% for the 21 possible comparisons, and this is also true for the direct relationship between the surface sample transmissions at the two wavelengths with $r_s = 0.902$. These correlations are independent of depth, and the coefficients are essentially constant among the five sets of transmission values that are available to the study as a result of the different calculations.

In terms of any inter-station light transmittance comparisons, the percent transmission data show an obviously opposite pattern in the study area streams in relation to what has been described for turbidity. In the case of transmission, a relatively high light penetration was obtained for the upper and middle East Poplar reaches which are located a short distance below Morrison Dam and which have low turbidity and suspended sediment levels. Light transmittance then declined somewhat into the lower East Poplar and the upper Poplar mainstem in conjunction with the pick-up of some sediment and turbidity as the waters moved further downstream in the drainage course, and comparatively low transmission values were also characteristic of the Middle Fork system with its high turbidity levels. Thus, the reduction of photosynthetic activity at the greater stream depths as a result any light extinctions by a water would be expected to be most pronounced in the Middle Fork and progressively less distinct upstream in the East Poplar River.

Water Color as an Affecting Factor. The fact that the three rank correlation coefficients listed above are somewhat removed from the 1.00 or the -1.00 value that would be descriptive of a perfect direct or inverse relationship between sets of numbers indicates that some factor in addition to suspended sediment-turbidity must have been influencing the light transmittance characteristics of the Poplar streams to some extent. Three lines of evidence point to water color as a possible affecting variable of this kind, and one of these pertains to the relative change that occurs in the extent of light transmittance by the 450 mu and 650 mu wavelengths when different levels of color are present in an aquatic system.

In uncolored or unstained waters, the shorter and more highly energetic blue wavelengths (e.g., 450 mu) typically penetrate to greater depths with higher transmissions than the longer and much less energetic red wavelengths (e.g., 650 mu). However, if a water is stained, this relationship between red and blue light transmissions is often changed because the substances coloring the water tend to absorb the blue light to a greater extent over the red so that the red light shows a greater transmission than the blue under a colored condition (Reid, 1961). This spectral shift is evident in the Poplar streams as illustrated in Table 8 wherein the 650 mu percent transmissions were consistently greater than the percent transmissions at 450 mu in all of the samples and at all of the depths.

As a further factor, a closer correlation was obtained in this study between turbidity and 650 transmission than was shown between turbidity and 450 transmission, and such a discrepancy would be expected if water color was an absorbant in the Poplar streams with the greater effect of this parameter directed to the penetration of blue light over the red wavelength. That is, red transmission and turbidity were primarily affected by the same factor (suspended sediment), producing a relatively high correlation coefficient, while blue transmission was also influenced by water color which would not affect turbidity and red transmission to as significant a degree, and this absorption discrepancy would produce the lower correlation coefficient that was established between the turbidity and 450 transmission variables. In addition, this same feature would also act to slightly lower the 650-450 transmission correlation below a 1.00 value. These relationships suggest that color is an influential factor in the study area streams, and it acts in concert with suspended sediment to reduce the light penetration of a water while also significantly changing the spectral quality of the light that does reach the deeper portions of a stream.

The availability of extra-study data which shows that the Poplar waters are colored to some extent provides the final piece of supporting evidence for the potential biotic importance of this particular water quality parameter in the Poplar area streams. Klarich (1978) calculated mean and median color values (as standard platinum-cobalt units) for the three Poplar forks at the international border as follows for the summer season: East Poplar--15 and 10 units for 32 samples; Middle Fork--13 and 15 units for seven samples; and West Fork--34 and 40 units for five samples. Higher colors approaching 100 units were obtained from some samples during other seasons of the year, and the USGS (1975-1979) also obtained relatively high values for the East Poplar at the border in more recent years (water years 1978 and 1979) with a color range of 6 to 55 units and with an average of 22 units for the warm weather months. Thus, the Poplar waters appear to be adequately colored to cause the changes and reductions in light transmission that were outlined previously since alterations of this kind have been observed in aquatic systems having color values in the vicinity of ten standard units (Reid, 1961).

General Reference Criteria. At water depths in the vicinity of 18 to 21 feet, the hydrostatic pressures that are exerted upon the freshwater aquatic macrophytes at these depths and at deeper locales begin to have deletrious effects on the plants, and this factor generally precludes the establishment and growth of these organisms in the deeper waters of a lentic system (Davis and Brinson, 1980). However, hydrostatic pressure is not a limiting factor in most streams, including those of the Poplar drainage, because of their less pronounced depths, and macrophytic plants can grow in waters with depths approaching 18 feet if light intensity is adequate for suitable photosynthetic rates and when other environmental aspects are amenable to their development. But in view of the light-quenching capacities of most natural waters with their light absorbing and reflecting suspended and dissolved materials, light availability is often a major restrictive factor in relation to plant growth and primary production in the deeper sections of a stream. The actual depths that are affected in this way depend upon the concentrations of the light impeding substances in the water.

At the same time, and because light is such a critical factor in aquatic systems, a large number of the submersant plants have become adjusted to the problem of light restriction by being able to efficiently photosynthesize under extremely low light intensities. This adaptation then acts to ameliorate to some extent the negative aspects of the light reductions that naturally occur to varying degress through any particular column of water. As a general rule of thumb, many of these plants are able to effectively photosynthesize and maintain themselves when light transmissions at their point of growth are only in the vicinity of two to three percent of the total irradiance at the surface of the water (Davis and Brinson, 1980). This two to three percent figure can then be used as a criterion for judging the likelihood of any light impedance problems with reference to macrophyte photosynthesis at the depths that are typical for the Poplar region streams.

Potential Biotic Effects. As indicated in Table 8, light-quenching should not be a significant environmental factor in the upper East Poplar (stations I, II, and III) during the summer and fall seasons in stream sectors that are less than five feet deep because of the high light transmissions in this reach that were always well above the 3% criterion for the evaluated depths and generally above 12% for both of the wavelengths. The clarity of the East Poplar in this segment is probably related to the sediment trapping action of Cookson Reservoir, and as a result of this clarity, adequate light should be available in this upper reach for macrophyte photosynthesis even in waters that approach ten feet in depth, although this extreme was not recorded for the river.

In the lower parts of the East Poplar (stations IV and V) however, some light restrictions did occur with the 450 mu wavelength at depths greater than two feet, and this quenching of the blue portion of the sun's spectrum could reduce photosynthetic efficiencies to some extent. But since the red transmissions were typically above 2% even at the four foot depth, the submersant macrophytes can probably maintain themselves in the lower East Poplar at these levels of water, although some retardation in plant growth might be anticipated as a result of the blue light restrictions. Because of the relatively low light transmissions in the lower East Poplar, light availability in this stream segment would be expected to become extremely important and potentially limiting at depths that are greater than four feet, and any reductions of macrophyte growth because of a light limitation should be most distinct in the extreme lower reach of the river (station V) at all of the depths in view of this segment's typically low red light percentages.

A conclusion on light availability that is similar to the one that has been developed for the lower East Poplar can also be directed to the upper Poplar mainstem (station VI) in the case where the turbidities of the reach happen to fall in the range of 4 to 6 NTU for a major portion of the summer-fall season. In this instance, adverse effects should not occur at depths that are less than two feet with adequately high blue and red transmissions while slight effects might be seen at depths between two and four feet because of a blue light extinction, and much more marked effects might be expected at these turbidities when stream depths exceed the four foot level since light reductions would be quite marked in these deeper waters. As a worse case, if the turbidities of the upper Poplar should happen to approach or surpass a 14 NTU value for an extended period of time, as was measured on the first sampling trip, then light-quenching at both the blue and red wavelengths would be adequately severe to be suggestive of inefficient photosynthetic rates and reduced plant growths in stream sectors that are not much deeper than two feet. However, additional transmission data will be needed to more specifically define the actual clarity regime of this particular stream segment.

Since the Middle Fork had relatively high turbidity values in the vicinity of 15 NTU, light-quenching at both the 450 and 650 mu wavelengths was found to be fairly pronounced in this more western stream (Table 8). As a result of this feature, reduced macrophyte photosynthetic rates and retarded plant development might be expected for the stream at depths that are greater than two feet, and such retardations could occur even at the 1.5 foot level since both the red and blue transmissions were often below 3% in these instances on each of the three site visitations. Of the seven appraisal sites, therefore, the adverse effects of an inadequate light penetration appear to be most distinct for the Middle Fork location (station VII), and reduced macrophyte biomass-canopy cover levels were anticpated from the plant inventory for the deeper sectors of this stream because of the operation of this particular environmental factor.

Temperature Levels

Major Observations. The temperature measurements that were made on each of the transect runs at a station during the three field trips to the study region are summarized in Table 9. Although these data are inadequate to completely describe the temperature regimes of the Poplar streams, some distinct patterns and features do become obvious in these numbers which help to characterize the temperature aspects of the aquatic systems in this drainage area.

On the one hand, the relatively high late July-early August daytime temperatures of the waters, as illustrated by the minimum, maximum, and average values in Table 9, indicate that the Poplar streams are basically warm-water in character as evidenced by the types of warm-water fish species that can be found in the drainage (Stewart, 1979). In relation to the physiological effects of this variable, such high temperatures allow for the development of the high summer levels of primary production that were projected for some of the stream reaches such as the middle segment of the East Poplar River. From this summer peak in temperature, this variable then declined by about 50% (by about ten degrees centigrade) through the second and third sampling trips into the fall months, and this seasonal temperature drop eventually culminates in the near zero readings that are obtained from the rivers during the winter period (Klarich, 1978).

In general, the data in Table 9 indicate that the summer temperatures of the drainage streams are well suited for the effective maintenance of compatible aquatic biota that have warm-water requirements. Temperatures that might be potentially lethal to these kinds of organismms were not encountered during the macrophyte survey.

In conjunction with the occurrence of plant senescence, the reductions in stream temperature that developed through the 1.5-month period from late July to mid-September also contributed to the seasonal decline in primary production that was observed for the inventory waters in terms of the pH and dissolved oxygen data. This temperature-related drop in production occurs because metabolic rates and the rates of enzymatic reactions inherently decrease by about 50% for each ten degree centigrade drop in temperature. Furthermore, such declines in Poplar temperature closely corresponded with the onset of macrophyte senescence that was identified for the region, and this parameter thereby could be the environmental factor that triggered the assumption of this life stage of the higher plants.

As noted earlier, the development of a senescent plant condition with the associated physiological deteriorations often results in a lowering of the primary production levels of a macrophyte community, and this influence of senescence on production can be accentuated by the metabolic effects that are directly related to the lower stream temperatures of the fall season. This sequence of events is then ultimately terminated in the northern latitudes by the extremely low temperatures of the winter months when the aquatic macrophytes are nonphotosynthetic, have totally senesced and died back to their dormant overwintering organs, and do not generally contribute to the production levels of an aquatic system during this period of the year. The spring season, in turn, brings about a reestablishment of the plant associations in the Poplar streams, and this regrowth then leads to the comparatively

Table 9. Summary of the stream temperature readings obtained during the course of this inventory from the seven Poplar River drainage appraisal sites in Montana.

Sampling	Visitation			Temperature in Degrees Centigrade*						
Station#	Date	and Time Period	No.	at Start of Run	at End of Run	Min. Temp.	and Time	Max. Temp.	and Time	Ave. Temp.
I-EP	7/30/80	0955-1425	11	20.0	21.8	20.0	1008	21.8	1420	20.9
II-EP	7/31/80	0910-1135	6	17.9	19.9	17.9	0918	19.9	1125	18.9
III-EP	7/30/80	1600-1805	6	22.0	24.7	22.0	1614	24.8	1743	24.0
IV-EP	7/31/80	1320-1505	6	22.0	23.4	22.0	1327	23.4	1458	22.6
V-EP	8/01/80	1215-1428	12	20.2	22.2	20.2	1218	22.2	1422	20.8
VI-MP	7/31/80	1555-1730	9	25.7	25.8	25.7	1602	26.0	1656	25.9
VII-MF	8/01/80	0930-1055	8	18.2	19.1	18.2	0933	19.1	1051	18.6
I-EP	8/28/80	1430-1555	6	18.3	18.7	18.3	1435	18.9	1508	18.7
II-EP	8/27/80	0935-1215	7	13.2	15.3	13.2	0948	15.3	1208	14.3
III-EP	8/27/80	1400-1600	7	16.8	17.3	16.8	1408	17.3	1555	17.1
IV-EP	8/28/80	1630-1838	6	20.2	19.3	19.3	1832	20.2	1635	19.6
V-EP	8/28/80	1145-1329	8	15.6	17.0	15.6	1150	17.0	1328	16.6
VI-MP	8/27/80	1655-1755	7	19.8	18.8	18.8	1750	19.9	1717	19.5
VII-MF	8/28/80	0945-1118	8	15.3	15.9	15.3	0950	15.9	1116	15.7
I-EP	9/17/80	1522-1610	7	10.8	10.7	10.7	1609	10.8	1526	10.8
II-EP	9/16/80	0855-1125	7	7.9	9.0	7.9	0903	9.0	1120	8.3
III-EPa	9/16/80	1335-1500	6	9.8	10.0	9.8	1340	10.0	1455	9.9
III-EPb	9/16/80	1745-1820	2	10.4	10.3	10.3	1815	10.4	1753	10.4
IV-EP	9/17/80	1040-1205	8	10.7	11.0	10.7	1045	11.0	1203	10.8
V-EP	9/17/80	0840-1025	8	10.7	11.1	10.7	0848	11.1	1023	10.9
VI-MP	9/17/80	1348-1458	12	11.7	11.6	11.6	1456	11.7	1351	11.7
VII-MF	9/16/80	1600-1700	10	13.0	12.6	12.6	1655	13.0	1602	12.8

*Temperature measurements were made during most of the macrophyte transect crossings at a station on each of the site visitations (sampling date), and the start, end, minimum (Min.) maximum (Max.), and average (Ave.) listings represent temperature values that were selected or calculated from a particular set of readings; No.--the number of temperatures that were obtained on a station trip. #EP--East Poplar stations, MP--main Poplar station, and MF--Middle Fork station; a and b--denote the occurrence of a split or time-separated appraisal run at a site.

high rates of primary production that tend to characterize these waters during the warm weather months.

Minor Observations. Other less important temperature patterns also become evident in the data of Table 9, and the more obvious of these can be briefly summarized as follows: For the most part, temperatures were found to be not only higher during the summer over the fall season, but they also demonstrated later day maximums with greater daytime variations during the warm weather periods of late July-early August than during the cooler days of mid-September. These types of inter-seasonal changes in temperature regimes can also affect the metabolic rates of the aquatic plants to some extent, and these influences should thereby be reflected in the water quality data of the streams.

In the case of the Poplar survey, greater differences between the maximum and minimum pH and dissolved oxygen values of a sample set were obtained from the summer collections than were obtained from the samples that were collected during the final site visitations, and these water quality discrepancies are in accord with the occurrence of temperature-based metabolic changes in the waters. Although such seasonally-related temperature variations with the associated biological and water quality alterations were observed to be distinctive in the Poplar drainage, adequate data could not be secured from this survey by which to definitely judge if any biologically significant temperature differences might occur among the separate stream locations, or to judge if the Cookson Reservoir might have a marked effect on the temperature characteristics of the East Poplar River and the upper Poplar mainstem.

The limited data in Table 9 are not suggestive of the occurrence of distinct and significant inter-station temperature differences, and they generally point to the absence of any marked early impoundment effects of the Cookson Reservoir on this variable in the East Poplar River. But future temperature monitoring should be continued in the Poplar region so that a more comprehensive temperature evaluation can be made of the East Poplar and the related streams after the development of extended post-impoundment conditions in the drainage.

PHYSICAL MEASUREMENTS

Introductory Information

Table 10 presents a summary of the number of transect lines that were run across the streams at each of the macrophyte appraisal sites. Table 10 also lists the number of transect points or perpendicular secondary lines that were evaluated among the several station transects for each of the six transverse stream sectors (edge of water to middle of stream) that were defined for the different sampling locations. As indicated by the table, the goal that was established for completing at least twenty transect crossings with more than 240 secondary lines at each of the seven stations was ultimately achieved by the inventory. However, only relatively small sets of transects could be run across the two riffle substations, involving only 115 or 128 transect points, because of the limited expanses of this type of stream segment within a close vicinity of any appraisal reach. In contrast, nineteen to 27 transects were run across the ponded segments of all of the

Table 10. The total number of transects and average inter-transect distances, the number of transect points by stream sector, and the total length of stream evaluated for aquatic macrophytes at each of the Poplar River drainage appraisal sites in Montana.

Sampling Station*	Number of Transects	Average Inter-Transect Distance in Feet	Length of Stream Assessed in Feet	Number of Transect Points by Stream Sector#						Total Number of Transect Points
				E	NE	IE	IM	NM	M	
I-EP	24	40.3	927	48	55	70	72	62	73	380
II-EP	21	19.2	384	42	49	59	57	62	62	331
III-EP	21	25.8	516	40	56	61	60	55	55	327
IV-EP	21	27.8	556	42	60	79	76	68	75	400
VR-EP	9	12.1	97	18	13	21	21	20	22	115
VP-EP	20	28.5	542	40	61	67	69	57	71	365
Totals	29	--	639	58	74	88	90	77	93	480
VIR-MP	9	22.3	178	18	21	20	25	22	22	128
VIP-MP	19	33.1	596	38	52	55	48	50	52	295
Totals	28	--	774	56	73	75	73	72	74	423
VII-MF	27	25.4	660	54	48	62	74	58	67	363
Grand Totals	171	--	4456	340	415	494	502	454	499	2704

*EP--East Poplar stations, MF--main Poplar station, MF--Middle Fork station, R--riffle, and P--pool.

#E--Edge of water, NE--near edge, IE--intermediate edge, IM--intermediate middle, NM--near middle, and M-middle of stream.

appraisal sites, and in these instances, between 290 and 400 total transect points were checked with around 40 to 70 transect points assessed for each of the individual stream sectors.

The actual number of secondary lines that could be tabulated at a site was primarily dependent upon the number of transects run and upon the width of the stream, and the variations in these factors largely account for the differences among the stations in the number of evaluated points; however, some degree of randomness was also involved in these applications. Stream depth, current velocity, and substrate texture determinations were made at each of the transect points as well as the macrophyte canopy cover and bare substrate assessments, and as a result of these evaluations, a great deal of physical and biological data were retrieved from the study area for the 2700 transect points that were eventually examined in the streams during the course of the three field trips to the Poplar drainage.

Table 10 also lists the average distance between adjacent transect crossings and the total length of stream that was assessed at each of the appraisal sites. The latter expression was calculated using the following equation: $L = A(T - 1)$, where L is the total length of the assessed station reach in feet, where A is the mean distance between adjacent transects in feet, and where T is the number of transects that were run at a site. The "L" values that are derived from this equation basically denote a length of stream that extends from the uppermost, upstream transect to the lowermost, downstream transect at each of the stations. This stretch of stream typically ranged between 500 and 670 feet with an average of 640 feet for the seven Poplar segments. However, much shorter distances were assessed at the two riffle sub-stations and in the case of one highly homogeneous ponded reach (station II), and a longer stretch of water was evaluated at the international border station on the East Poplar because of its generally nonuniform morphometry and its largely nonhomogeneous macrophyte compositions.

Stream and Sector Widths

Table 11 summarizes the average widths of the study area streams along the particular segment that was evaluated for the aquatic macrophytes, and these numbers are identical to the values that describe the average lengths of the various transect crossings that were made at each of the appraisal sites. As indicated by the table, the riffle segments prescribed relatively narrow stream sections in comparison to the ponded reaches, although the Middle Fork location also afforded a relatively narrow reach for evaluation even though it was non-riffle in character. On the other hand, one of the lower East Poplar stations (IV) was distinct in an opposite fashion by providing a rather wide stream segment. Otherwise, the more typical average widths of the ponded reaches ranged from 29.4 feet in the upper East Poplar to 43.4 feet in the upper Poplar mainstem, and an overall average of about 34 feet was obtained from all of the stations.

By definition, the widths of the five transverse instream sectors that were developed for the project as a means of partitioning the macrophyte and physical data are essentially identical for any single transect crossing. But because of the differences in stream width and the corresponding variations in the average length of a transect at the different stream locations,

Table 11. The typical widths of the Poplar drainage streams at the macrophyte appraisal sites and their depth characteristics by stream sector.

Sampling Station*	Average Width in Feet	Average Depth (Ave.) and Typical Maximum Depth (Max.) in Feet by Stream Sector#												Station Mean	
		E		NE		IE		IM		NM		M			
		Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.
I-EP	33.6	0.15	0.33	0.52	0.90	0.64	1.17	0.68	1.18	0.70	1.25	0.66	1.10	0.58	0.99
II-EP	29.4	0.23	0.57	0.69	1.23	1.05	1.65	1.40	1.87	1.52	1.94	1.71	2.03	1.16	1.55
III-EP	37.4	0.29	0.71	0.99	1.52	1.42	1.91	1.68	2.10	1.95	2.39	2.12	2.73	1.45	1.89
IV-EP	66.6	0.23	0.50	0.82	1.46	1.13	1.80	1.35	2.03	1.62	2.18	1.79	2.17	1.24	1.69
VR-EP	16.9	0.12	0.28	0.32	0.59	0.49	0.60	0.49	0.79	0.54	0.82	0.57	0.74	0.44	0.64
VP-EP	38.5	0.14	0.37	0.57	1.35	1.12	2.31	1.42	2.83	1.76	3.24	1.94	3.17	1.24	2.21
VIR-MP	19.2	0.06	0.13	0.13	0.23	0.18	0.30	0.22	0.40	0.27	0.46	0.27	0.50	0.19	0.34
VIP-MP	43.4	0.20	0.53	0.62	1.52	1.04	1.99	1.40	2.24	1.56	2.33	1.67	2.37	1.11	1.83
VII-MF	19.0	0.62	1.04	0.82	1.46	1.03	1.59	1.12	1.63	1.19	1.60	1.29	1.70	1.03	1.50
Basin Means	33.8	0.23	0.50	0.61	1.14	0.90	1.48	1.08	1.67	1.23	1.80	1.34	1.83	0.94	1.40

*EP--East Poplar stations, MP--main Poplar station, MF--Middle Fork station, R--riffle, and P--pool.

#E--Edge of water, NE--near edge, IE--intermediate edge, IM--intermediate middle, NM--near middle, and M--middle of stream.

the widths of these sectors did vary to some extent among the transects and the sampling stations. Most commonly, the sector widths, involving the left-side and right-side sub-sectors, ranged from 5.9 feet to 8.7 feet from station to station with an average of 6.8 feet for all of the sites. However, smaller sectors ranging between 3.3 and 3.9 feet were assessed for the relatively narrow riffle and Middle Fork reaches while larger sectors on the order of 13.3 feet were assessed at the broader station IV segment on the lower East Poplar River. But in spite of these variations, all of the instream sectors did have identical widths when viewed from a relative scale, and they equalled 20% of the transect length for the middle sector and about 10% plus 10% of the transect length for the left and right sub-sectors of the near edge, intermediate edge, intermediate middle, and near middle parcels.

As a further factor, the relative distance of any one of the station sub-sectors from the closest shore was also identical through all of the stations. As examples, the midpoint of the middle stream sector was equal to 50% of the transect length in all cases while the midpoints of the left and right near middle sub-sectors equalled 35% of the transect distance when starting from the nearest bank. The percentage midpoint distances of the other sectors stood at 5%, 15%, and 25% with the edge location having a value of zero percent. Such relative sector width and distance similarities are important in relation to the data assessments of the inventory since this feature provides the framework for allowing the inter-station comparisons of the sets of numbers that were developed for the same stream sector but obtained from different appraisal sites and thereby from potentially different absolute distance positions within the streams.

Stream Depths

General Descriptions. The average depths of the six stream sectors at each of the sampling sites are presented in Table 11, and for comparative purposes, the mean stream depths of each of the stations across all of the sectors are included in the table as well as the mean depths of each of the sectors across all of the appraisal locations. In addition, the "typical" maximum depths of the sectors and the stations are summarized in Table 11 as calculated following the definition of this variable that was described earlier in the report.

As might be expected, depths at most of the appraisal sites markedly increased from the edge of water sector to the middle of the stream with an approximate six-fold average increase in this variable for all of the stations. These intra-site changes in depth from sector to sector were generally more pronounced nearer to the shore than they were near the center of a river, and this aspect is illustrated by the "basin means" in Table 11. Station I on the East Poplar was quite distinctive in this regard with relatively minor depth increases from the intermediate edge position to the central portion of the stream after a marked increase in depth through the first three demarcations. This same feature also became evident to some extent in the two riffle segments and in the Middle Fork reach, while the other drainage reaches demonstrated somewhat more consistent and noticeable changes in depth through all of the instream locations.

On an overall basis, a fairly wide range of mean depth was noted for the many sectors that subdivided the Poplar drainage streams. Extremely shallow waters were typically encountered at the start of a transect crossing where depths were commonly less than 0.3 of a foot and occasionally less than 0.1 of a foot for some of the shore-near shore transect points. In contrast, much deeper waters were waded near the middle of most of the stream segments with depths typically ranging between 1.25 and 2.25 feet for the middle-near middle sectors of the ponded reaches but approaching 3.25 feet for a few of the deeper locales.

Depths also varied to a considerable degree among the appraisal sites and between the riffle and ponded types of stream morphometries as illustrated by the "station means" in Table 11, and these inter-station depth differences were most obvious at the midstream locations. In the case of the 1.25 to 2.25 foot midstream depth range that was most characteristic of the ponded reaches, the Middle Fork segment was found to occur in the lower part of this sequence with somewhat shallow characteristics, while some of the stations on the East Poplar River provided depths that fell into the upper part of this same range. Stations III and VP were particularly distinctive for the study region because of the relatively high average depth readings from the near midstream sectors and because of the high maximum values that were measured at some of the secondary lines when making the transect runs at these two sites. The riffle segments were oppositely distinct because of their generally reduced depths through all of the sectors, and station I was also unique for a non-riffle reach because of the surprisingly shallow waters that were observed in this extreme upper stretch of the East Poplar River.

Edge of the Water Descriptions. The Middle Fork segment also proved to be somewhat unique for the study region by demonstrating comparatively deep edge of water secondary lines in relation to the lower values that were typically obtained from this sector at the other appraisal sites. This feature is suggestive of the consistent occurrence of fairly steep stream banks along the Middle Fork reach with a pronounced separation between the terrestial and aquatic systems of this particular drainage. In the case of some of the other stations, the relatively deep maximum values that were measured for the edge of water position on a few of the transect runs point to the occasional occurrence of distinct stream banks at a scattered set of reach locations. But in the main, the waters of this sector were observed to be relatively shallow on most of the transect crossings at the non-Middle Fork stations, and this feature is then indicative of a much more gradual transition from a terrestial to an aquatic mode in the East Poplar and upper Poplar mainstem than was the case for the Middle Fork reach.

Most of the river segments in the Poplar drainage, thereby, revealed a predominantly non-cutbank type of channel morphometry through the inventoried section which points to the occurrence of fairly stable hydrologic conditions. But any variations in the disposition of the shore sector of a stream could result in inter-reach differences in the kinds of aquatic macrophyte taxa that might become established at these edge of water locations.

Potential Biotic Effects. The generally wide variations in depth that have been noted for the Poplar drainage streams in relation to the different river reaches, transverse sectors, and morphometric configurations would be expected to have some direct physical influences upon the composition of the aquatic plant assemblages that might be found at any of the stream locations. That is, some of the waters would be expected to be too shallow to allow for the establishment and development of luxurious and submersant higher plant weedbeds and the ecesis of underwater macrophytes that have the larger plant morphologies. At the same time, other waters would be expected to be too deep to allow for an extensive growth of the emergent aquatic forms, and these deeper segments could also restrict certain of the truly aquatic taxa that might have a shallow water requirement. As a result, differently organized macrophyte associations might be found in those sectors and stream segments that happen to be relatively shallow in nature versus some of the other locales that can be characterized by their much greater depths. The potential action of this variable on the plant communities of the Poplar basin will be described and illustrated more fully when reviewing the actual canopy cover data that were collected during the course of this inventory.

In addition to the direct effects of depth, this variable in conjunction with the optical density of a water can also be an important influential factor on macrophytic growth in terms of the amount of light that penetrates to the submersant plants. These indirect relationships have been considered previously, but the potential influence of reduced light transmissions on plant photosynthesis can be more specifically evaluated for the different stream sectors-stations by comparing the depths in Table 11 to the transmission values that are presented in Table 8.

The data in Tables 8 and 11 indicate that major transmission problems should not become evident for any of the sectors in the upper and middle East Poplar reaches (stations I to IV) because of the clarity of the water in these particular segments. In addition, such difficulties should not become apparent in the riffle reaches (stations VR and VIR) and in the edge, near edge, and intermediate edge sectors of stations VP, VIP, and VII because of the shallow nature of these stream locations. However, some reductions in photosynthetic activity and plant growth as a result of reduced light transmissions to the macrophytes could occur in the more midstream sectors of the latter three stations because of the greater depths and the higher optical densities of these down-drainage waters. Such potential effects can be summarized as follows.

Specific Relationships to Light Transmission and Stream Production. In the case of station VP on the lower East Poplar, no adverse transmission effects on stream production would be expected at the average midstream depths of this reach (less than two feet). However, as the waters approach the maximum values for the segment, i.e., near three feet, the blue light transmissions appear to be lowered below the two to three percent photosynthetic reference criteria which could reduce photosynthetic rates to some extent. But the influences of this kind in the lower East Poplar are best judged as being relatively mild because the red light transmissions remain well above this reference level even at the maximum depths of this reach.

With respect to station VIP on the upper Poplar mainstem, no negative influences on the macrophytes from reduced light penetrations are again foreseen at the average depths of the three middle stream sectors even at the higher turbidity values of the water because of the generally shallow nature of these typical mid-river transect points. But when the maximum depths of the segment are encountered with waters in excess of two feet, and if the turbidities of the reach should prove to be relatively high for an extended period (in the vicinity of 16 NTU), then rather severe reductions in light transmission could occur for both the blue and red wavelengths, and this feature could distinctively retard plant growth in the deepest sections of the stream. However, if the turbidities of the upper Poplar mainstem should prove to be more typically located at the lower end of the range that is presented in Table 8 (closer to 6 NTU), then the reductions of light transmission would not be adequate in the deeper waters to produce such marked effects on the macrophyte growth patterns of the reach. Much less severe biotic effects are therefore anticipated for this low turbidity case, and such effects should be largely similar to those that have been described for station VP.

As noted previously, the negative influence of such lowered light penetrations on submersant macrophyte photosynthesis was expected to be greatest in the Middle Fork reach (station VII) because of its comparatively high turbidity and generally low percent transmission values. However, a comparison of the data in Tables 8 and 11 indicate that such effects should be relatively mild at the average depths of the station segment (less than 1.3 feet) because of the relatively shallow nature of these waters. As a worse case, some blue light restrictions could occur near the middle of the stream at the typical depths of the reach, but since the red transmissions at these same positions do not appear to be reduced below the reference criteria, the related physiological effects should not be very pronounced.

As another option, when the Middle Fork depths happen to approach the maximum levels that were measured at some of the sectors (in the vicinity of 1.5 to 1.7 feet), fairly distinct blue light extinctions do become evident in the water. This development therefore, especially when coupled with the occurrence of some red light restrictions, could cause significant reductions in the photosynthetic and growth rates of aquatic macrophytes in the deeper portions of the river. In general, only moderate increases in the overall turbidities of the Poplar Middle Fork would be needed to cause some rather significant light absorptions even at the more nominal depths of the reach, and these turbidity enhancements could have some pronounced physiological repercussions on the submersant plants that inhabit this particular borderline stream.

Current Speeds

Low Flow Velocities. For obvious reasons, the presence or absence and the magnitude of a current velocity in a stream is another physical factor that can have a marked effect on the composition, occurrence, and prevalence of aquatic macrophyte communities and taxa in any particular lotic system, and an extensive review of the influence of current speed on these plants is available in Butcher (1933). The average current velocities that were obtained in this inventory for each of the six stream sectors of a station are presented in Table 12 for each of the Poplar appraisal sites, and the percentage of transect points in each of the station sectors that demonstrated immeasureable velocities (near zero current speeds) after the application of a standard pygmy current meter to a secondary line is also included

Table 12. Current velocity characteristics of the Poplar drainage streams at the seven macrophyte appraisal sites.

	Average Current Velocity (Vel.) in Feet per Second by Stream Sector# and the Percentage of Transect Points in Each Sector Demonstrating a Zero Velocity												Station Mean	
	E		NE		IE		IM		NM		M			
Sampling Station*	Vel.	%Zero	Vel	%Zero	Vel	%Zero	Vel.	%Zero	Vel.	%Zero	Vel.	%Zero	Vel.	%Zero
I-EP	0.00	100.0	0.02	90.9	0.07	61.4	0.13	48.6	0.17	39.3	0.22	38.6	0.111	60.4
II-EP	0.00	100.0	0.00	100.0	0.001	98.3	0.03	80.7	0.09	62.9	0.22	29.0	0.063	76.1
III-EP	0.00	100.0	0.007	94.6	0.007	91.8	0.03	75.0	0.07	43.6	0.07	38.2	0.031	73.1
IV-EP	0.00	100.0	0.00	100.0	0.00	100.0	0.00	100.0	0.008	91.2	0.02	84.0	0.005	95.5
VR-EP	0.03	88.9	0.08	61.5	0.26	28.6	0.24	19.0	0.40	5.0	0.38	13.6	0.248	33.0
VP-EP	0.00	100.0	0.009	98.4	0.02	92.5	0.02	85.5	0.05	63.2	0.08	52.1	0.034	80.5
VIR-MP	0.00	100.0	0.03	81.0	0.11	55.0	0.24	29.2	0.32	4.8	0.41	0.0	0.191	43.2
VIP-MP	0.00	100.0	0.00	100.0	0.01	90.9	0.02	77.1	0.02	82.0	0.03	61.5	0.015	84.7
VII-MF	0.003	98.1	0.003	97.9	0.003	98.4	0.004	97.3	0.01	87.5	0.03	71.2	0.010	91.4
Basin Means	0.004	98.6	0.017	91.6	0.053	79.7	0.079	68.0	0.126	53.3	0.162	43.1	0.079	70.9

*EP--East Poplar stations, MP--main Poplar station, MF--Middle Fork station, R--riffle, and P--pool.

#E--Edge of water, NE--near edge, IE--intermediate edge, IM--intermediate middle, NM--near middle, and M-middle of stream.

in the table. In addition, sector or "basin means" across the stations and "station means" across the sectors are summarized in Table 12 for both the velocity and the percentage expressions.

Relatively low current speeds were consistently measured near the shores of the Poplar streams with high percentages of zero measurements at these same locations. Marked increases in velocity with lower zero percentages then developed towards the center of the rivers, and the main thread of current typically occurred through the two midstream sectors of the inventory reaches. But on an overall basis, and because of the largely pooled morphometry of the streams, the current velocity variable was not particularly distinctive for the Poplar drainage during the period of study in light of an average of only about 0.08 of a foot per second (fps) for all of the sectors-stations and with approximately 71% of these transect lines showing no measurable current values.

Summer-fall velocities were much more distinct in the two riffle segments than in the ponded reaches as described by the station means in Table 12, but even the midstream currents of the riffles (between 0.30 and 0.45 fps) were not very pronounced in comparison to the velocities that typically exceed 0.5 fps in many lotic systems. Furthermore, speeds in the ponded segments of the Poplar streams were much lower than those in the riffles with values typically less than 0.1 fps and with more than 73% of the secondary lines in the ponded reaches showing no current readings. These observations suggest that current velocities during the low flow warm weather months were not adequately high to be a major factor in relegating the complete absence of macrophytic vegetation from most of the Poplar segments. As a result, the summer-fall current speeds of these rivers appear to be of such a magnitude so as to exert a relatively subtle influence on the macrophyte communities of the drainage instead of an "all or nothing" effect that could cause the total elimination of a plant association at the higher velocity values.

Of the ponded segments, warm weather current velocities were significantly higher in the station I reach on the upper East Poplar than they were at the other sites, and this suggests that the station I stretch is probably best classified as having a channel morphometry whose current speeds and depths are intermediate between those of a true riffle and those of a more obviously ponded stretch of water. Therefore, current velocities in the station I reach, along with those of the riffle segments, would be expected to have a greater effect on the aquatic macrophytes of the stream than the velocities of the other segments with their much lower values. In the case of all of the stations, the influence of current should be more pronounced in the midstream locations than in the sectors that are located nearer to the shore. In general, current speeds were observed to be particularly low in the pools of stations IV, VIP, and VII, and they were generally most distinct in the pools of the upper portion of the East Poplar River.

Runoff Velocities. The above discussion refers only to the low flow velocities that characterize the study area streams during the summer and fall seasons. However, velocities could develop during the spring runoff period that would be suitably high with the large discharge volumes to have a direct scouring effect on the macrophyte communities of the rivers. This scouring action on the streams would then become evident at a later time during the year by the generally low plant biomass levels that would be evident in the affected segments. In relation to the Poplar system, spring scouring should be most distinct in the Middle Fork and sequentially less pronounced in an upstream direction from the main Poplar to the upper East Poplar River where the Cookson impoundment would have an increasingly greater effect in controlling the volumes of water in the drainage and in depressing the related current speeds that would emanate from the runoff events.

No data are on hand from this study with which to judge the actual influence of spring runoff on the macrophyte communities of the Poplar streams. But the occurrence of spring runoff should be viewed as a potentially important environmental feature that could differently effect the various appraisal reaches of the drainage, especially with reference to the recent closure of Morrison Dam, and it could then represent a causal factor for explaining any macrophytic biomass variations that might become evident among the different Poplar reaches.

Stream Bottom Characteristics

Substrate Reference or Index Numbers.

The nature of the bottom materials in a stream is another physical variable that can have a marked influence on the abundance and composition of a water's aquatic macrophyte communities where, in the extreme case, extensive growths of rooted aquatic plants would not be expected in a reach having substrates composed entirely of large rocks and boulders. Because of this importance, substrate evaluations were made at each of the transect points of this inventory, and the approach that was used has been described previously with a unitless substrate reference number or index providing the main end product of the assessment.

By definition, the substrate index can range from one to eight with the numbers that are closer to one indicative of a fine-grained substrate in the stream segment with the bottom sediments composed primarily of mucks and silts. Index values that are closer to eight, in turn, point to a high abundance of the coarse-grained materials such as the larger rocks, and the intermediate index numbers in the vicinity of four are suggestive of a more intermediate-grained substrate composition with a likely dominance of the streambed by the gravels which are representative of a medium particle size. Table 13 presents the average substrate reference numbers that were obtained from the transect points in each of the six stream sectors at each of the appraisal sites, and this table also contains the "basin means" for each of the sectors along with the "station means" for each of the sampling locations.

As indicated in Table 13, the substrate reference numbers that were obtained from the study region varied to a considerable extent among the various stream sectors of the different appraisal sites. This index ranged from several sectors in the ponded reaches that had index values equal to or very close to one, indicating the presence of a muck and silt stream bottom, to one riffle sector that had a reference number slightly over five which points to a dominance of the gravels and the larger rocks in this particular streambed locale. The changing nature of the substrate materials through the Poplar streams is additionally illustrated in Table 13 by the differences in the station index means across the sectors, ranging from about one to near four, and also by the differences in the basin means of the sectors across the several appraisal sites which ranged from about two to approximately three units. As a result of these substrate features, some inter-

Table 13. Substrate reference numbers of the Poplar drainage streams at the seven macrophyte appraisal sites by stream sector.

Sampling Station*	Edge#	Near Edge	Intermediate Edge	Intermediate Middle	Near Middle	Middle#	Station Mean
I-EP	1.09	1.13	1.24	1.38	1.61	1.57	1.35
II-EP	1.10	1.02	1.00	1.00	1.01	1.02	1.02
III-EP	1.34	1.21	1.41	1.59	1.71	1.70	1.50
IV-EP	1.04	1.05	1.16	1.61	2.24	2.67	1.68
VR-EP	3.97	3.31	3.50	4.12	4.50	5.07	4.14
VP-EP	1.76	1.81	1.93	2.29	2.41	2.60	2.17
VIR-MP	3.42	4.12	4.70	3.31	3.79	4.38	3.94
VIP-MP	2.82	3.14	3.45	3.64	4.01	3.96	3.53
VII-MF	2.08	2.73	2.84	3.21	3.38	3.57	3.00
Basin Means	2.07	2.17	2.36	2.46	2.74	2.95	2.48

*EP--East Poplar stations, MP--main Poplar station, MF--Middle Fork station, R-riffle, and P--pool.

#Stream sectors--edge of water to middle of stream.

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station and intra-station variations in the characteristics of the aquatic macrophyte communities might be anticipated from stream location to stream location in response to the differences in stream bottom materials that were observed for Poplar inventory area.

Velocity Relationships. In many lotic systems, the typical size of the substrate particles in a reach is directly related to the magnitude of the dominant current velocity of that stream segment where the fine-grained materials would not be expected to be very common in stream sections having consistently high current speeds; rather, the mucks and silts should be most dominant in the more slowly moving waters. This relationship is illustrated by the basin mean data of Table 13 with sectors located nearer to the shore having lower substrate index numbers in conjunction with their lower current velocities (Table 12) than the more midstream sectors with their greater current speeds. In fact, a perfect rank correlation is obtained between the mean reference numbers of the six sectors and their average current velocities. This same relationship also holds when comparing the riffle reaches and the pools with the riffles having higher index values and much higher current speeds than the ponded segments of the streams.

However, a correlation between substrate texture and current velocity does not prove to be valid if the station means of the pools are considered, and a statistically insignificant rank correlation ($r_s = 0.23$) was obtained between the average substrate index numbers and the average current velocity values of the six ponded segments. But because of the advent of various run-off events, this non-correlation does not indicate that current is totally unimportant in defining the nature of the bottom materials in the ponded stream reaches.

In the pool comparisons of the inventory, the substrate index was found to be highly and significantly correlated ($r_s = 0.93$) with the magnitude of the designated station numbers (one to seven) which describe a downstream direction in the basin. This then suggests that the substrate characteristics of the different stream reaches are probably dependent to some extent on the degree of scouring that is developed in a reach from spring runoff and other runoff events since this action would be expected to be increasingly more severe along a down-drainage vector, producing the coarser materials that are seen in the lower segments of the drainage. Of course, an enhanced current velocity represents one component of the scouring action that develops during the life cycle of a distinctive runoff period. Thus, both the current velocities at the time of sampling and those that occurred prior to sampling during the spring season of the inventory and earlier years probably acted in concert to define the types of substrates that were observed at any one of the stream positions within the Poplar basin.

Substrate Class Percentages. Table 14 provides a somewhat different representation of the substrate characteristics of the stream sectors by listing the percentage of transect points in each case denoting muck-silt, fine-grained, and coarse-grained materials. The fine-grained substrates consist of the mucks and silts plus the sands so that the muck-silt category is actually a subset of the fine-grained classification. The coarse-grained substrates consist of the gravels and the larger rocks and boulders of the drainage. As might be expected, the magnitudes of the substrate reference numbers are closely related to the percentages listed in Table 14 where the higher index values are associated with the sectors having the greater percentages of gravels and rocks.

The data in Table 14 indicate that the fine-grained and coarse-grained substrates were about equally represented in the study region, although their proportions varied to a considerable degree among some of the stream sectors. The mucks, silts, and sands were found to be most prevalent in the upper and middle East Poplar reaches with relatively small percentages of the gravels and rocks, while the coarse-grained materials were much more common in the lower East Poplar, the Poplar mainstem, and the Middle Fork. In the main, the proportion of the larger sized substrate particles tended to increase downstream in the basin, and as a result of this feature, different kinds of aquatic macrophyte communities might be anticipated for the upper versus the lower reaches of the drainage because of such broad-based differences in the nature of their bottom materials. In essence, it appears that substrate should be one of the major factors to influence the distribution and the prevalence of aquatic macrophytes in the study area.

MACROPHYTE DATA PRESENTATIONS AND CHARACTERIZATIONS BY APPRAISAL SITE

EXPLANATION OF TABLES

The purpose of this chapter of the report is to present in a tabular form the quantitative plant data that were obtained during the macrophyte inventory, and this section also discusses in a general fashion this plant information with reference to each of the appraisal sites. Therefore, each of the following data tables contains a listing of the true taxon percent canopy cover (TCC) and the weighted taxon percent canopy cover (WCC) values of the different aquatic plants that were field-recognized at a station when

Table 14. Substrate characteristics of the Poplar drainage streams at the seven macrophyte appraisal sites by stream sector expressed as the percentage of transect points denoting muck, fine-grained (F.G.), and coarse-grained (C.G.) bottom materials.

Sampling Station*	Edge#			Near Edge			Intermediate Edge			Intermediate Middle			Near Middle			Middle#			Station Mean		
	Muck	F.G.	C.G.	Muck	F.G.	C.G.	Muck	F.G.	C.G.	Muck	F.G.	C.G.	Muck	F.G.	C.G.	Muck	F.G.	C.G.	Muck	F.G.	C.G.
I-EP	87.5	95.8	4.2	85.5	94.5	5.5	65.7	95.7	4.3	56.9	91.7	8.3	44.3	86.9	13.1	42.9	90.0	10.0	62.0	92.3	7.7
II-EP	83.3	100.	0.0	95.9	100.	0.0	100.	100.	0.0	100.	100.	0.0	98.4	100.	0.0	95.2	100.	0.0	96.1	100.	0.0
III-EP	52.5	97.5	2.5	73.2	92.9	7.1	78.7	83.6	16.4	68.3	71.7	28.3	58.2	58.2	41.8	58.2	60.0	40.0	65.7	76.5	23.5
IV-EP	92.9	100.	0.0	96.7	96.7	3.3	88.6	89.9	10.1	60.5	60.5	39.5	26.5	26.5	73.5	8.0	9.3	90.7	59.3	60.5	39.5
VR-EP	16.7	38.9	61.1	15.4	38.5	61.5	0.0	23.8	76.2	0.0	0.0	100.	0.0	0.0	100.	0.0	0.0	100.	4.3	14.8	85.2
VP-EP	37.5	72.5	27.5	34.4	68.9	31.1	32.9	53.7	46.3	24.6	33.3	66.7	26.3	36.8	63.2	22.5	29.6	70.4	29.0	47.1	52.9
VIR-MP	22.2	33.3	66.7	4.8	14.3	85.7	0.0	0.0	100.	0.0	4.2	95.8	0.0	0.0	100.	0.0	0.0	100.	4.0	8.0	92.0
VIP-MP	13.2	44.7	55.3	3.8	28.8	71.2	0.0	14.5	85.5	0.0	8.3	91.7	0.0	0.0	100.	1.9	1.9	98.1	2.7	15.3	84.7
VII-MF	13.0	75.9	24.1	8.3	47.9	52.1	9.7	41.9	58.1	2.7	28.4	71.6	0.0	17.9	82.1	0.0	13.6	86.4	5.3	36.1	63.9
Basin Means	46.5	73.2	26.8	46.4	64.7	35.3	41.7	55.9	44.1	34.8	44.2	55.8	28.2	36.3	63.7	25.4	33.8	66.2	36.5	50.1	49.9

*EP--East Poplar stations, MP--main Poplar station, MF--Middle Fork Station, R--riffle, and P--pool.

#Stream sectors--edge of water to middle of stream.

making the transect runs. As a further feature, these taxon canopy covers have been blocked or separated according to the six stream sectors that were defined for the project with the IE and IM designations denoting the intermediate edge and intermediate middle sectors respectively. In addition, overall canopy covers are listed on a station basis for each of the taxa as calculated from all of the sectors, and overall canopy covers are presented for each of the six sectors at a station as established from all of the taxa. Also, grand total true and weighted station canopy cover percentages are included in the tables as determined from all of the transect points that were evaluated at a sampling site.

The individual taxa are organized in each of the data tables so that the completely emergent aquatic plants--*Carex*, *Equisetum* (*Equis.*), *Juncus*, *Mentha*, *Scirpus*, and *Typha*--are presented first in this same order with the amphibious plants--*Eleocharis* (*Eleoch.*), Poaceae, *Hippuris* (*Hipp.*), *Saggitaria* (*Sag.*), and *Sparganium* (*Sparg.*)--listed as a second group and with the completely submersant plants combined as a third category--Characeae (Char.), *Heteranthera* (*Heter.*), Musci, *Myriophyllum* (*Myr.*), *Potamogeton filiformis* (*P. fil.*), *P. foliosus* (*P. fol.*), *P. pectinatus* (*P. pec.*), *P. richardsonii* (*P. ric.*), *P. robbinsii* (*P. rob.*), *P. vaginatus* (*P. vag.*), and *Zanichella* (*Zan.*). The bottom algae (B. Algae) and the floating algae (F. Algae) are then listed as a fourth category of plants. The absence of any one of these taxa from a data table indicates that this macrophyte or algal group was not encountered when completing the quantitative inventory work at that particular stream segment. The canopy covers of the amphibious macrophytes have been blocked and are separately presented in the tables on the basis of their emergent (E) and submersant (S) forms, and the total and overall canopy covers (CC) of the stations and the stream sectors have also been blocked in this same manner.

The various canopy cover derivations that have been noted above represent the main core of quantitative information that was obtained from the project, although other quantitative expressions are also included into the data tables which should help to additionally characterize the nature of the aquatic macrophyte communities in the study area streams. This includes the percent occurrence of bare substrates (Bare Sub.) at each of the sectors and stations along with the magnitude of the vegetative canopy cover (Veg. CC) that was recorded at each of these same stream locations. The tables also list the transect frequencies (TF) or longitudinal frequencies of the taxa at an appraisal site as well as the average category biomass rankings (ABio) of these plants across all of the station sectors. In addition, an ABio value is presented for each of the sectors at a station across all of the taxa as is an overall ABio number of the entire station. Furthermore, the average numbers of taxa that were recorded for each of the vegetated transect points in a sector and at a sampling site are included in these tabular summaries. All of these expressions plus the canopy cover items have been defined and described earlier in the report.

As a final data manipulation, a variation of the bare substrate expression has been calculated which includes the nonvegetated point tabulations of a sector plus the secondary lines in the same sector that happened to denote the occurrence of bottom or floating algae but the absence of any "true" macrophytes from that particular stream section. Thus a vegetated canopy cover percentage that describes only the true macrophytes to the exclusion of the bottom and floating algae can be determined by simply subtracting this adjusted substrate expression (Bare-Alg.) from 100%. This extra manipulation is not very important with reference to many of the stream sectors since the Bare-Alg. value is only slightly greater than the Bare Sub. percentage in a large number of the cases. However, distinct discrepancies between the two expressions do become evident in relation to a few of the sectors and stations where the algae happened to be much more predominant, and in these instances, the Bare-Alg. variable does afford a somewhat different perspective of the nature of these somewhat distinctive mancrophyte communities.

EAST POPLAR RIVER AT THE INTERNATIONAL BOUNDARY--STATION I

Floral Characteristics

Dominant Taxa. The 24 transect runs that were completed at station I were initiated very close to the international boundary in the general vicinity of the USGS border gaging station, and they continued downstream at about forty-foot intervals for 927 feet where the final transect crossing was made. As indicated in Table 15, fifteen macrophyte taxa plus the two broad algal groups were recognized in the field along this reach, and these numbers denote a relatively high level of station floral diversity for the drainage with the other appraisal sites demonstrating between ten and twenty field-recognized plant taxa including the two algal categories. The emergent *Sagittaria* and *Scirpus* genera, the amphibious *Eleocharis*, and the submersant *Potamogeton pectinatus* species were observed to be the dominant plants of the station I stream segment in a descending order of CC percentages, and these four macrophytes accounted for 82% and 67% of the weighted and true total canopy cover levels of the station with the bulk of the taxa therefore providing only a small percentage of the plant tabulations.

Such a dominance of the plant community by a small set of taxa as illustrated by the data in Table 15 is characteristic of all of the Poplar stations, and it is a common feature of most biological systems as described by Whittaker (1970). With reference to the Poplar drainage, between 70% and 89% of the total weighted canopy cover, and between 67% and 82% of the total true canopy cover levels of the inventoried segments were put forth by the four most abundant taxa of an appraisal site.

Subdominant and Minor Taxa. In addition to the four dominant taxa of station I, *Carex* and *Sparganium* were also observed to be fairly prevalent in the extreme upper reach of the East Poplar River in Montana. However, although the sedges, like the four most abundant plant representatives, were quite ubiquitous along this segment with high TF and somewhat high TCC values, this same genus was not very conspicuous at the appraisal site as described by its relatively low WCC and Abio numbers in Table 15. The bur-reed genus in contrast, though not particularly ubiquitous in this upper East Poplar segment with low TF and TCC percentages because of its nonoccurrence at most of the station I secondary lines, was, nonetheless, a generally conspicuous floral component of the reach with a high ABio rating because of its high biomass levels and pronounced vertical postures at the small set of transect points at which it was found.

The remaining eight higher plant taxa at station I, e.g., *Hippuris*

Table 15. Summary of aquatic macrophyte data: East Poplar River at the international boundary (station I).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E *Carex*	8.75	54.17	4.55	16.36	0.43	4.29	0.00	0.00	0.00	0.00	0.00	0.00	1.84	10.00	75.0	1.84
E *Mentha*	0.21	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.26	4.2	1.00
E *Scirpus*	26.04	47.92	34.00	58.18	13.71	21.43	2.78	9.72	4.51	9.67	3.56	5.48	12.68	22.89	100.	5.54
E *Eleoch.*	16.87	41.67	2.00	5.45	1.00	4.29	0.00	0.00	0.00	0.00	0.68	1.37	2.74	7.11	62.5	3.85
S *Eleoch.*	0.00	0.00	0.18	1.82	0.14	1.43	1.39	2.78	0.16	1.61	0.00	0.00	0.34	1.32	12.5	2.60
E Poaceae	4.58	12.50	0.36	3.64	0.14	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.66	2.37	20.8	2.78
E *Hipp.*	1.25	4.17	2.36	7.27	0.14	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.53	1.84	25.0	2.86
E *Sag.*	1.67	8.33	8.73	36.36	16.00	37.15	17.78	36.11	13.39	22.58	15.62	23.29	12.97	28.16	91.7	4.61
S *Sag.*	0.00	0.00	1.09	10.91	3.71	7.14	8.19	23.61	3.39	14.52	6.71	13.70	4.23	12.37	62.5	3.43
E *Sparg.*	0.00	0.00	1.09	3.64	1.43	1.43	1.53	2.78	1.61	1.61	0.00	0.00	0.97	1.58	8.3	6.17
S *Sparg.*	0.00	0.00	0.00	0.00	0.71	1.43	1.39	1.39	0.00	0.00	2.05	2.74	0.79	1.05	12.5	7.50
S Char.	0.00	0.00	0.00	0.00	0.29	2.86	0.00	0.00	1.61	3.23	1.92	8.22	0.68	2.63	20.8	2.60
S *Myr.*	0.42	4.17	1.27	12.73	1.43	8.57	0.97	4.17	0.32	3.23	0.68	6.85	0.87	6.58	45.8	1.32
S *P. fil.*	0.00	0.00	0.00	0.00	0.00	0.00	0.28	2.78	0.16	1.61	0.14	1.37	0.11	1.05	12.5	1.00
S *P. pec.*	0.00	0.00	1.63	9.06	2.43	7.15	3.75	8.34	4.19	6.45	0.82	2.74	2.23	5.79	33.3	3.86
S *P. ric.*	0.00	0.00	0.00	0.00	0.14	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.26	4.2	1.00
S *P. vag.*	0.00	0.00	0.00	0.00	0.14	1.43	0.00	0.00	0.00	0.00	0.14	1.37	0.05	0.53	4.2	1.00
S *Zan.*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	2.74	0.16	0.53	8.3	3.00
B. Algae	0.00	0.00	0.18	1.82	0.71	7.14	0.97	9.72	1.61	16.13	0.55	5.48	0.71	7.11	37.5	1.00
F. Algae	1.04	2.08	1.09	3.64	0.86	2.86	0.00	0.00	0.16	1.61	0.00	0.00	0.47	1.58	16.7	3.00
Total CC	60.83	177.08	58.55	170.91	43.43	112.86	39.03	101.39	31.13	82.26	33.70	75.34	43.11	115.00	--	3.75
E CC	59.38	170.83	53.09	130.91	32.86	71.43	22.08	48.61	19.52	33.87	19.86	30.14	32.42	74.21	--	4.37
S CC	1.46	6.25	5.45	40.00	10.57	41.43	16.94	52.78	11.61	48.39	13.84	45.21	10.68	40.79	--	2.62
Veg. CC	87.50	87.50	90.91	90.91	84.29	84.29	76.39	76.39	62.91	62.91	64.38	64.38	76.84	76.84	--	--
Bare Sub.	12.50	12.50	9.09	9.09	15.71	15.71	23.61	23.61	37.09	37.09	35.62	35.62	23.16	23.16	100.	--
Bare-Alg.	12.50	12.50	10.91	10.91	22.86	22.86	29.17	29.17	51.61	51.61	39.73	39.73	28.95	28.95	--	--
ABio	--	3.44	--	3.43	--	3.85	--	3.85	--	3.78	--	4.47	--	3.75	--	--
Taxa/Pt.	--	2.02	--	1.88	--	1.34	--	1.33	--	1.31	--	1.17	--	1.50	--	--

vulgaris, Zanichella palustris, and Potamogeton richardsonii, were representative of largely non-ubiquitous and inconspicuous aquatic macrophytes in the station I segment by having low CC, TF, and ABio values. Furthermore, the two algal categories plus the Characeae can also be added to this listing by providing only a small percentage of the total canopy covers of this upstream site.

Community Characteristics

Abundance Rankings and Variations. The station I location on the East Poplar River is unique for the drainage by showing a marked dominance of its emergent aquatic plants over its generally non-dominant submersant forms, and it is the only appraisal site where the ECC levels of the entire station were greater than the submersant percentages in a distinctive fashion. In addition, although the ECC levels of the extreme upper East Poplar did decline towards the middle sector of the reach as was the case for all of the sampling sites, the emergent plants were present in a relatively high abundance all across the stream, and this feature was not generally observed in the other inventory reaches. As a result, station I can be ranked first among the sites on the basis of its ECC levels. However, it has to be ranked sixth in relation to its submersant forms, and because of the low abaundance of the fully aquatic plants, station I has only a fifth ranking among the sites with reference to its total canopy cover percentage.

Because of the station I drop in ECC levels towards the center of the river, the total sector canopy covers also demonstrated a parallel and gradual 45% decline in a midstream direction. The SCC values, however, provided a somewhat different pattern at this site with a marked increase from the edge to the IM sector but with a slight decline in SCC then occurring from the IM segment to the middle portion of the stream. For the most part, the other Poplar stations demonstrated generally similar across the river variations in the SCC levels of their six transverse stream sectors.

Association Compositions and Diversity-Biomass Aspects. The dominance of the emergent macrophytes in the channel-like station I segment was probably due to the shallow nature of the waters in this part of the river in conjunction with the predominantly fine-grained substrate compositions, and it appears that the emergent forms were able to out-compete the totally submersant plants because of this somewhat novel depth-substrate combination. Along with Sagittaria, Potamogeton pectinatus was observed to be an important member of the submersant plant association at the border location, although this species was tabulated in comparatively low CC levels. The fennel-leaved or Sago pondweed was most prevalent in the intermediate IE to NM portions of the appraisal site, and it was the only fully aquatic macrophyte that proved to be a very conspicuous component of the station I reach. Scirpus and Sagittaria, in turn, were the dominant members of the pronounced emergent plant association at this site with the bulrushes and many of the other emergents most abundant near the shore but with the arrowheads most abundant in the more central sections of the stream.

The high abundance of Sagittaria was one of the major distinctive floristic features of the extreme upper part of the East Poplar River in Montana. In addition, station I represents the only Montana site at which Potamogeton vaginatus was collected in the Poplar drainage, and this identification further distinguishes the flora of the station I reach to some extent. Since P. vaginatus has also been recognized in the Canadian portion of the basin, the plant's extremely low CC reading at the first inventory position on the East Poplar just south of the border suggests that the international boundary may denote the southern-most extension of its range within the Poplar region.

Floral diversities of the transect points at station I were greatest in the edge of water sector of the reach with an average of about two taxa tabulations for each of these secondary lines. The Taxa/Pt. values then markedly declined to the center of the stream where the secondary lines of the middle sector were almost mono-floristic in character, although they did have somewhat higher biomass levels than the near shore points because of the slight increase that occurs in the ABio numbers from the bank to the midstream section. On a site basis, the total Taxa/Pt. ratio of station I was comparatively low with reference to the other appraisal sites, prescribing a generally low transect point diversity, but this segment did provide a fairly high overall ABio reading with the emergent plants much more pronounced in this regard than the submersant taxa. In spite of the low Taxa/Pt. ratio however, the floral diversity of the entire station was relatively high as a result of the field-recognition of 17 plant taxa and algal groups in this particular inventory reach.

General Physiognomy. In association with station I's high overall ABio value, this appraisal site also exhibited a relatively low TCC/WCC ratio (2.67) which is again descriptive of high plant biomass levels at the vegetated transect points. Nevertheless, the vegetative canopy cover of the station was not particularly pronounced with a fifth ranking among the sites, and the corresponding occurrence of nonvegetated transect points was most prevalent near the middle of the stream with an edge of water to midstream decline in the Veg. CC variable. This combination of a low TCC/WCC ratio with a somewhat low Veg. CC percentage indicates that the plants of the extreme upper East Poplar River tended to assume a "mound-type" of physiognomy which was most obvious near the center of the reach. But since Veg. CC was not excessively low with about 75% of the secondary lines providing plant tabulations, the general appearance of this macrophyte community is probably best described as being intermediate between one that is dominated by such distinct plant aggregations or "mounds" and an association that is characterized by its thick, largely continuous, and luxurious aquatic weedbeds.

In the case of station I, the mounds were formed by the scattered clumps of out-of-water or underwater Sagittaria that were found all across the stream and interspersed by bare substrates or by the presence of inconspicuous submersant forms. The weedbeds, in turn, were represented primarily by the near shore and emergent stands of Scirpus and Eleocharis, and distinct growths of submersant Potamogeton pectinatus were encountered at a few random locations throughout the reach.

This tendency towards a mound-type of plant organization in the station I segment was paralleled both by the comparatively high current velocities of the reach and by its relatively high bare substrate frequencies as illustrated by the 100% TF value for the Bare Sub. variable. Thus, current speed along with depth and substrate might be invoked as a causal factor for the unique plant community characteristics of the upper East Poplar at the international border. In any event, the plant association of this reach did make the closest approach of any of the Poplar sites to the mound-type of vegetative arrangement that is generally described by a low TCC/WCC ratio and by a low Veg. CC percentage.

EAST POPLAR RIVER NEAR THE INTERNATIONAL BOUNDARY--STATION II

Community Characteristics

Abundance Rankings and Variations and Upstream Comparisons. The 384-foot station II reach on the upper-East Poplar River in Montana was located about one mile south of the international boundary, and the plant data that were obtained from this appraisal site are presented in Table 16. As suggested by the table, this station probably had the most distinctive aquatic macrophyte community of the nine stream segments that were examined during the survey with relatively high submersant and emergent canopy cover levels (ranked second and third respectively) and with the highest total canopy cover percentage and floral diversity of any of the sites. Furthermore, its emergent plants were found to be present in a fairly high abundance at all six of the sectors, although this emergent association did demonstrate a marked decline in canopy cover from the shore to the center of the stream.

As a result of the station II midstream drop in ECC, and unlike the observation at station I, total emergent canopy cover for the station II reach was greatly exceeded by that for the submersant forms with a much higher overall SCC level at the second station over the first case. In addition, even though the emergent plants were somewhat common in the more midstream sectors of station II, they were much less pronounced at these locations than what was tabulated for the more upstream segment, and the emergent plants were not continuously present all across the stream on any of the station II transect crossings as has been noted for many of the station I transect runs. But because of a general transverse increase in SCC in opposition to the ECC decline, station II did demonstrate generally high total CC levels completely across the river but with a drop in total CC into the two midstream sectors and with a slightly lower value at the bank of the stream.

Thus stations I and II on the East Poplar, though revealing some vegetative likenesses (e.g., a similar pattern of change in SCC across a reach), were also quite disparate in some aspects of their plant communities, and such differences and similarities were probably related to the particular blend of similarity and dissimilarity in the nature of their physical features. That is, station I had shallower depths and more rapid current velocities than station II with station II providing a moderate depth factor and somewhat high current speeds withrespect to the rest of the appraisal sites. Like station I, the station II reach was dominated by the fine-grained bottom materials, but station II was particularly distinctive in this regard in comparison to station I and the other Poplar drainage segments.

Site-Specific Diversity and Biomass Aspects. In addition to the high canopy cover levels, station II also provided the greatest floral diversity of any of the sites with the field-recognition of eighteen aquatic macrophyte taxa plus the two algal groups as listed in Table 16. As observed

Table 16. Summary of aquatic macrophyte data: East Poplar River near the international boundary (station II).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E *Carex*	4.76	19.05	3.47	18.37	1.36	6.78	0.18	1.75	0.00	0.00	0.00	0.00	1.39	6.65	57.1	2.09
E *Equis*.	0.48	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.60	9.5	1.00
E *Mentha*	0.48	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.60	4.8	1.00
E *Scirpus*	30.48	45.24	20.82	32.65	1.86	3.39	0.00	0.00	0.00	0.00	0.00	0.00	7.28	11.17	85.7	6.51
E *Typha*	13.34	19.05	16.94	22.45	19.83	23.73	14.21	17.55	8.55	16.13	5.16	9.68	12.75	17.82	66.7	7.15
E *Eleoch*.	5.95	21.43	3.47	10.20	0.17	1.69	0.00	0.00	0.00	0.00	0.00	0.00	1.30	4.53	42.9	2.87
E Poaceae	8.34	26.19	2.65	10.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.45	4.83	42.9	3.00
E *Hipp*.	3.21	9.52	2.86	14.29	1.95	10.07	0.00	0.00	0.00	0.00	0.00	0.00	1.18	5.14	38.1	2.29
S *Hipp*.	0.83	4.76	1.22	6.12	0.42	1.69	0.00	0.00	0.00	0.00	0.00	0.00	0.36	1.81	14.3	2.00
E *Sag*.	2.38	4.76	12.25	30.61	3.05	10.17	1.58	8.77	1.13	4.84	0.16	1.61	3.17	9.67	57.1	3.28
S *Sag*.	0.24	2.38	0.00	0.00	1.02	10.16	0.35	3.51	0.00	0.00	0.00	0.00	0.27	2.72	38.1	1.00
E *Sparg*.	0.00	0.00	3.06	4.08	3.39	5.08	0.00	0.00	0.00	0.00	0.00	0.00	1.06	1.51	14.3	7.00
S *Sparg*.	0.00	0.00	0.00	0.00	1.69	3.39	0.88	1.75	0.00	0.00	0.32	3.23	0.51	1.51	19.0	3.40
S Char.	0.00	0.00	2.24	14.29	2.20	8.47	1.75	3.51	0.97	3.23	0.00	0.00	1.21	4.83	47.6	2.50
S *Heter*.	0.24	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.30	4.8	1.00
S *Myr*.	0.95	9.52	13.47	69.39	31.02	81.36	39.12	75.44	25.33	59.67	14.68	30.65	21.87	55.89	95.2	3.91
S *P. fil*.	0.00	0.00	0.20	2.04	0.51	5.08	0.88	1.75	0.32	3.23	0.16	1.61	0.36	2.42	28.6	1.50
S *P. pec*.	0.00	0.00	1.63	16.33	8.31	35.59	20.35	50.87	29.52	69.35	39.68	67.74	18.19	43.20	100.	4.21
S *P. ric*.	0.00	0.00	0.20	2.04	1.19	5.08	1.06	10.52	2.26	9.67	0.81	1.61	1.00	5.14	19.0	1.94
S *P. rob*.	0.00	0.00	0.20	2.04	1.02	3.39	1.05	3.51	0.32	3.23	1.13	4.84	0.66	3.02	28.6	2.20
S *Zan*.	0.00	0.00	0.20	2.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.30	4.8	1.00
B. Algae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.61	0.32	3.23	0.09	0.91	14.3	1.00
F. Algae	0.00	0.00	1.22	4.08	1.19	5.08	3.16	8.77	1.13	4.84	0.00	0.00	1.15	3.93	42.9	2.92
Total CC	71.67	173.80	86.12	261.22	80.17	220.34	84.56	187.72	69.68	175.81	62.42	124.19	75.44	188.52	--	4.00
E CC	69.64	157.14	65.51	142.86	31.61	61.02	15.96	28.07	9.68	20.97	5.32	11.29	29.73	62.84	--	4.73
S CC	2.02	16.67	20.61	118.37	48.56	159.32	68.60	159.65	60.00	154.84	57.10	112.90	45.71	125.68	--	3.64
Veg. CC	100.0	100.0	95.92	95.92	98.31	98.31	98.25	98.25	96.77	96.77	96.77	96.77	97.58	97.58	--	--
Bare Sub.	0.00	0.00	4.08	4.08	1.69	1.69	1.75	1.75	3.23	3.23	3.23	3.23	2.42	2.42	33.3	--
Bare-Alg.	0.00	0.00	4.08	4.08	1.69	1.69	1.75	1.75	3.23	3.23	4.84	4.84	2.72	2.72	--	--
ABio	--	4.12	--	3.30	--	3.64	--	4.50	--	3.96	--	5.03	--	4.00	--	--
Taxa/Pt.	--	1.74	--	2.72	--	2.24	--	1.91	--	1.82	--	1.28	--	1.93	--	--

for station I, the algae in general, but particularly the bottom forms, were not overly conspicuous in the station II reach, although the floating algae did become somewhat more prevelant downstream on the East Poplar than at station I with the development of a moderately high TF value. In the main, therefore, the true macrophytes were found to be the dominant components of the aquatic plant communities in the study region but with the algae providing for a sequentially greater proportion of the total canopy covers of the stations in a down-drainage direction and in the riffle segments of the streams.

Along with a high floral site diversity, station II also afforded the highest transect point diversity of the inventoried stream segments with an average tabulation of nearly two different taxa for each of the station's secondary lines. The overall ABio level of the station can also be given a high classification which is indicative of the occurrence of relatively distinct plant biomass levels in this particular stream segment. Floral point diversity was observed to be quite pronounced in the NE and IE sectors of station II where the emergent and submersant associations of the reach tended to converge and coincide, and it was somewhat lower in the edge and in the IM and NM sectors where the plant associations were more purely emergent or submersant in composition. Furthermore, this Taxa/Pt. value was particularly low in the middle sector where the submersant plants were largely dominant, and the transect points were almost mono-floristic at this midstream location as has been noted for the station I reach.

At the same time, the ABio's of the individual sectors were found to be generally high all across the station II segment without any distinct or consistent pattern of increase or decrease towards the center of the stream. However, the ABio's were slightly lower in the ecotonal NE and IE sectors where the greatest floral diversity was identified for the reach. In addition, and similar to the case for station I, the total station II ABio value for the emergent association was greater than that for the submersant plant grouping even though, and unlike station I, the underwater taxa provided the highest overall TCC and WCC readings for the site. As a result, the emergent plants were somewhat more obvious than the submersant association in the station II reach because of the emergents' more pronounced vertical postures and larger morphologies, but the submersants did afford a higher overall density when the entire station is used for an overview. In contrast, the out-of-water plants dominated both the biomass and the density aspects of the aquatic vegetation at station I.

General Diversity and Biomass Relationships. As a general observation, the ABio and Taxa/Pt. values of the stream sectors tended to be inversely related at those ponded segments having high station plant abundance and diversity levels. In these cases (stations I to VP), rank correlation coefficients between the ABio and Taxa/Pt. variables ranged from -0.73 to -0.94 with these r_s coefficients typically statistically significant at the 5% level. As a result, stream sectors having highly ranked floral diversities at a site, such as the more heterogeneous intermediate locales that defined an emergent-submersant ecotone in the stream, generally had the lower ranking biomass levels. In opposition, the sectors nearer to the edge or the middle of a stream, describing fairly homogeneous emergent or submersant plant growths respectively, generally provided the lower ranking diversities but with the more highly ranked biomass levels.

The diversity-biomass relationships described above are fairly obvious in the station II data, but the negative correlations between the ABio and the Taxa/Pt. numbers tend to break down in the riffle sections and in the down-drainage ponded segments with their low overall abundance and diversity characteristics. In these instances (stations VP, VIR, and VIP), statistically insignificant rank correlation coefficients ranging between -0.37 and 0.15 were obtained from the appraisal sites with the Middle Fork (station VII) providing an intermediate but insignificant r_s value of -0.64. Thus, the comparatively depauperate plant associations of the down-drainage, riffle, and Middle Fork reaches demonstrated a relatively simplistic type of community organization in contrast to the more complex East Poplar associations as exemplified by the station II reach with its marked macrophytic development.

General Physiognomy. Similar to the calculations directed to station I, the low total TCC/WCC ratio of station II (2.50), like its high ABio value, also points to the occurrence of high macrophytic abundances at the vegetated secondary lines of this particular appraisal site. But unlike station I, station II provided extremely high vegetative canopy cover percentages and low bare substrate frequencies in all of the sectors, and this involves the tabulation of aquatic plants at almost all of the transect points of the reach. The combination of a low TCC/WCC value and a high Veg. CC value indicates that station II on the East Poplar prescribed a distinctive weedbed-type of plant association with the presence of continuously thick and dense and vertically pronounced macrophyte growths entirely across the stream. This kind of plant grouping stands in contrast to macrophyte community at station I with its tendency towards a broken mound-type of development, and these organizational dissimilarities can be related to the differences in the physical characteristics of the two separate stream segments.

Floral Characteristics

Dominant Taxa and Upstream Comparisons. As indicated in Table 16, the submersant *Myriophyllum spicatum* and *Potamogeton pectinatus* species and the emergent *Typha* and *Scirpus* genera dominated the station II flora in a descending order of abundance. All four of these taxa provided generally high WCC, TCC, and TF percentages with *Typha* and *Scirpus* additionally pronounced by virtue of their extremely high ABio values. *M. spicatum*, *P. pectinatus*, and *Scirpus* were also tabulated in the station I reach with the latter two taxa again recorded as plant dominants in this more upstream segment. However, the pondweeds were found at much greater abundance levels at station II than at station I, while the reverse was true for the bulrushes which were somewhat more distinct at the station I locales. In contrast to the bulrushes, *M. spicatum*, though dominant at station II, was not overly prevalent in the boundary segment of the East Poplar with low WCC and ABio readings, and *Typha* was not actually encountered when making one of the transect crossings at this same border reach.

As suggested by the above discussion, several distinct floristic differences become evident between the station I and station II segments even though they were located only one mile apart on the same river. As an example, the abundance of the emergent cat-tails at the station II location acts as one feature that floristically distinguishes this appraisal site from the other inventory reaches since this plant was tabulated with very low canopy covers at only one other Poplar station (IV). Similarly, the emergent Equisetum genus was identified only from the station II reach, but the scouring-rushes were not as floristically distinct as the cat-tails for this segment because they were found in very low abundance levels.

Subdominant and Minor Taxa and Upstream Comparisons. Additional floristic differences between the two stations are seen in the relatively low canopy covers of Eleocharis and Sagittaria at station II in contrast to the dominance of these plants at station I. Sagittaria can probably be classified as a subdominant at station II by being moderately abundant in this reach as a carry-over from the upstream waters, but the arrowheads had much lower WCC, TCC, TF, and ABio values at station II than in the upstream locations. Carex and Sparganium, in turn, which might be rated as subdominants at station I, were largely inconspicuous members of the station II flora, although the bur-reeds were somewhat distinct at station II as expressed by their high ABio readings. Like Carex, Sparganium, and Eleocharis, most of the other taxa that were tabulated in the station II reach, except for the four dominants and Sagittaria, can also be classified as relatively inconspicuous floral components of the water with Equisetum, Mentha arvensis, Heteranthera dubia, and Zanichella palustris being the most notable in this regard. Nevertheless, all of the station II taxa, regardless of their abundance levels, do make a contribution to the high floral diversity characteristics of this particular East Poplar segment.

Association Compositions and Abundance Relationships Among Taxa. The distinctive and submersant aquatic weedbeds of station II were dominated by M. spicatum and P. pectinatus with the remaining underwater plants making only minor canopy cover contributions to this plant association. Both of these dominant species demonstrated low SCC values in the shallow edge of water sector with its high emergent tabulations, and P. pectinatus then sequentially increased in abundance to the much deeper midstream sector in concert with the gradual decline in the emergent plants. M. spicatum, in turn, also markedly increased in abundance from the edge to the IM sector where it was most prevalent, but unlike P. pectinatus, it then showed a sharp drop in canopy cover to the center of the stream where P. pectinatus was observed to be most abundant.

The varying canopy cover relationships among station II plants are suggestive of the operation of inter-taxa competition between the emergent and submersant forms and between the two dominant submersant species. These inter-sector CC variations also point to the occurrence of differing physical requirements among these same macrophytes with P. pectinatus tending to favor the deeper waters where it out-competed the milfoils in the central parts of the stream. M. spicatum, in contrast, was most successful at the intermediate depths, and it out-competed the pondweeds in the shallower section of the reach. As might be expected, the emergent plants were most successful in the shallow waters with the submersant macrophytes more at home with the deeper depths, and the two dominant submersives were much more competitive in the reach than the less abundant submersant forms.

In the case of the emergent plant association at station II, the pronounced aquatic weedbeds were represented by the dense stands of Scirpus and Typha that were found all along the segment as indicated by their high TF percentages. Scirpus was most prevalent and dominant over Typha in the shallow E and NE locations while being absent from the three middle sectors, and Typha showed an increase in canopy cover from the edge sector to become dominant over Scirpus in the deeper IE position. However, Typha then showed a subsequent drop in abundance to the deepest, midstream portions of the river. Thus Scirpus was more competitive than Typha in the shallower waters of station II while the reverse was true at the more moderate depths, and both of these dominant plants were able to out-compete the other emergent taxa to some extent, e.g., the sedges and the spike-rushes, throughout the entire stretch of the reach. But the deeper waters acted to restrict the growth of all of the emergent plants to a considerable degree with these depth effects more pronounced on the bulrush than on the cat-tail stands. Such negative influences of stream depth on the emergent plant associations were observed to be even more distinct in the next downstream station on the East Poplar with its generally deeper waters.

EAST POPLAR RIVER SOUTH OF THE INTERNATIONAL BOUNDARY--STATION III

Floral Characteristics

Dominant Taxa and Upstream Comparisons. The 516-foot station III reach that was inventoried in the study region is located between 1.5 and two miles below the United States-Canadian border in close proximity to the station I and II segments on the upper East Poplar River. The plant data obtained from this third station on the river, as summarized in Table 17, are suggestive of a relatively high floral diversity in the station III waters as was observed for the two upstream sites with the field-recognition of sixteen macrophyte taxa plus one of the two algal groups.

As indicated by Table 17, the Characeae (primarily Chara but with some Nitella), Myriophyllum spicatum, Potamogeton pectinatus, and P. richardsonii, ordered according to their descending canopy cover levels, denote the four most prevalent, ubiquitous, and conspicuous plants in the station III segment by having generally high CC, TF, and ABio values. Although M. spicatum and P. pectinatus were also found to be dominant taxa in one or two of the upper stations with this feature then carried downstream into the third appraisal site, both the Characeae and P. richardsonii were only tabulated in small quantities at these upstream locations in contrast to their dominance in the station III reach. Thus, the high abundances of the latter two taxa act to floristically define station III from the remaining Poplar sampling sites, and the floral distinctiveness of the station was particularly pronounced in terms of the Characeae because of this taxa's markedly high ABio values. These observations further point to the pronounced floral variations that can be seen in the East Poplar River even along a relatively short and generally ponded 1.5- to two-mile stretch of the stream.

Subdominant and Minor Taxa and Upstream Comparisons. Station III can be further characterized floristically as a result of the moss identification that was made for the reach since this is the only sampling location in the drainage where a bryophycean representative was actually retrieved from a stream. However, a floral separation of station III from the other sites on the basis of this unique moss collection is not as distinct as that for the Characeae because this single bryophycean taxon was uncovered in extremely low abundance levels along the station III segment.

Table 17. Summary of aquatic macrophyte data: East Poplar River south of the international boundary (station III).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E *Carex*	16.25	50.00	4.64	25.00	2.62	6.56	0.00	0.00	0.00	0.00	0.00	0.00	3.27	11.62	81.0	2.82
E *Eleoch*.	4.75	27.50	0.36	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	3.98	47.6	1.62
S *Eleoch*.	0.00	0.00	0.00	0.00	0.82	1.64	0.33	3.33	0.91	1.82	0.18	1.82	0.40	1.53	14.3	2.60
E Poaceae	4.75	27.50	0.89	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	3.67	42.9	2.00
E *Hipp*.	1.25	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.31	4.8	5.00
S *Hipp*.	0.00	0.00	0.36	3.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.61	9.5	1.00
E *Sag*.	0.25	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.31	4.8	1.00
S *Sag*.	1.25	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.31	4.8	5.00
E *Sparg*.	0.25	2.50	0.18	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.61	4.8	1.00
S Char.	0.00	0.00	1.25	5.36	14.75	29.51	30.33	50.00	46.91	63.64	38.91	63.64	22.97	37.00	81.0	6.21
S *Heter*.	0.25	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.31	4.8	1.00
S Musci	0.00	0.00	0.18	1.79	0.33	3.28	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.92	4.8	1.00
S *Myr*.	1.25	12.50	31.96	82.14	33.93	65.58	17.00	45.00	9.82	29.09	8.55	34.55	18.16	46.79	100.	3.88
S *P*. *fil*.	0.00	0.00	0.18	1.79	0.33	3.28	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.92	9.5	1.00
S *P*. *fol*.	0.00	0.00	0.00	0.00	0.00	0.00	0.17	1.67	0.18	1.82	0.00	0.00	0.06	0.61	9.5	1.00
S *P*. *Pec*.	0.75	7.50	3.21	17.86	3.11	11.48	7.50	25.00	9.64	18.18	16.55	23.64	7.00	17.74	57.1	3.94
S *P*. *Ric*.	1.25	12.50	7.50	25.00	6.23	29.50	6.83	28.34	3.09	9.09	2.91	14.55	4.86	20.49	85.7	2.37
S *P*. *Rob*.	0.00	0.00	0.18	1.79	0.49	4.92	0.17	1.67	0.00	0.00	0.18	1.82	0.18	1.84	14.3	1.00
S *Zan*.	0.00	0.00	0.00	0.00	1.15	4.92	2.17	8.33	2.91	5.45	0.91	1.82	1.25	3.67	14.3	3.42
F. Algae	4.25	10.00	8.21	32.14	0.16	1.64	0.17	1.67	0.00	0.00	0.00	0.00	1.99	7.34	52.4	2.71
Total CC	36.50	160.00	59.11	203.57	63.93	162.30	64.67	165.00	73.45	129.09	68.18	141.82	62.20	160.55	--	3.87
E CC	27.75	115.00	6.07	32.14	2.62	6.56	0.00	0.00	0.00	0.00	0.00	0.00	4.92	20.80	--	2.37
S CC	8.75	45.00	53.04	171.43	61.31	155.74	64.67	165.00	73.45	129.09	68.18	141.82	57.28	139.76	--	4.10
Veg. CC	85.00	85.00	96.43	96.43	86.89	86.89	86.67	86.67	90.91	90.91	92.73	92.73	89.91	89.91	--	--
Bare Sub.	15.00	15.00	3.57	3.57	13.11	13.11	13.33	13.33	9.09	9.09	7.27	7.27	10.09	10.09	52.4	--
Bare-Alg.	15.00	15.00	3.57	3.57	13.11	13.11	13.33	13.33	9.09	9.09	7.27	7.27	10.09	10.09	--	--
ABio	--	2.28	--	2.90	--	3.94	--	3.92	--	5.69	--	4.81	--	3.87	--	--
Taxa/Pt.	--	1.88	--	2.11	--	1.87	--	1.90	--	1.42	--	1.53	--	1.79	--	--

In opposition to the Bryophyceae, the sedges were observed to occur throughout the study region, and this genus, which was determined to be a fairly prevalent taxon at the two upstream sites, demonstrated a slightly enhanced canopy cover percentage when going into the station III segment where it can again be rated as a subdominant plant of the reach. *Zanichella* and *Eleocharis*, in turn, were only slightly abundant at this third appraisal site with *Zanichella* showing a downstream increase in canopy cover from station I to station III but with *Eleocharis* prescribing a downstream drop in abundance through these same three locations. The floating algae were also observed to be slightly abundant on the station III waters, and this observation coincides with the general down-drainage increase in algal prevalence that has been noted for the Poplar basin. However, the true macrophytes, which include the Characeae, were still highly dominant in the East Poplar River by accounting for 97% of the total station III weighted canopy cover, and this dominance is additionally exemplified by the lack of any bottom algal tabulations from the station III sectors.

But regardless of the high total macrophyte abundance at station III, about 50% of the station's taxa, including the mosses, four of the pondweed species, and the grasses, as examples, were largely inconspicuous members of the flora at the site with typically low CC, TF, and ABio values, and these minor taxa contributed to only 3% of the total canopy cover levels of the site. In the case of station III, *Sagittaria* and *Sparganium* have to be added to this minor taxa listing even though they were important components of the upstream plant communities, and this discrepancy provides a further illustration of the marked floral variations of the Poplar streams. Furthermore, *Scirpus* and *Typha* were not observed to be present along the station III reach although these two genera were conspicuous elements of the station I and/or station II macrophyte associations.

Pondweed-Milfoil Competitive Relationships. As described for station II, Table 17 also presents evidence of inter-specific competition and differing physical requirements among the four dominant plants of the third appraisal site where both *M. spicatum* and *P. pectinatus* demonstrated patterns of transverse change in CC across the stream that were similar to those that were obtained for each of the same two taxa in the next upstream site. That is, both of these species provided low abundances at the shallow edge of water sector in the face of stiff competition from a fairly dense emergent association, and *M. spicatum* was found to be most successful and most competitive with its greatest SCC levels at the more moderate current velocities and stream depths of the NE and IE sectors where the emergent plants were seen to be inconspicuous and largely unimportant.

At the same time, *P. pectinatus* was observed to be most prominent with higher SCC values than *M. spicatum* near the center of the river in conjunction with the greater depth and current speed measurements that were secured from this midstream location. But in the case of station III, the Characeae also act as significant submersant competitors which was not the case for the upstream sites because of the family's low abundance levels in the station I and II segments. The dominance of the charophytes at station III, thereby, further complicates the biological interactions of this more downstream macrophyte community.

Comparisons Between Emergent Associations. These relatively pronounced negative interrelationships between the canopy cover levels of certain of the submersant taxa, as has been described for the station II and III segments, were not very obvious in the station I reach because of the dominance of the emergent plants in these shallow waters. This emergent dominance was then reflected in the low abundance levels of the submersant forms at the border site. In contrast, and with the possible exception of the edge of water sector, the emergent taxa did not prove to be a major competitive force in the deeper station III reach, and because of this fact, the varying canopy cover patterns among the more prevalent submersant plants could then become evident against this reduced background noise.

In the main, the noncompetitive emergent plant association at station III was not particularly distinctive in the study region in being dominated by the fairly ubiquitous but diminutive Carex and Eleocharis forms which did not provide for a very dense or vertically pronounced physiognomy with their relatively low TCC and ABio values. However, these two genera did afford a relatively high TF percentage. As a result, the generally inconspicuous but widespread Carex-Eleocharis emergent association along the station III reach stands in stark contrast to the thick, luxurious, and vertically distinct Scirpus-Sagittaria and Scirpus-Typha emergent associations that were examined along the more upstream segments of the East Poplar River near the international boundary.

Additional Evidence of Inter-Taxa Competition. Like P. pectinatus, the Characeae appear to have a requirement for generally deep waters in order to achieve their maximum development since this taxon also demonstrated an increasing canopy cover level in conjunction with the greater depths that occurred toward the center of the station III reach. This feature indicates that the unique dominance of these macrophytic algae in this particular segment was probably at least partly related to the fact that the station III stretch of the East Poplar consistently revealed the deepest waters on the average of any of the appraisal sites, and this same reach also afforded fairly deep maximum depths at some of the station locations. With the exception the shallow edge and near edge sectors therefore, the Characeae were more competitive and more abundant than the pondweeds at station III through all of the deeper sectors. However, the charophytic SCC levels did show a slight drop from the NM to M sector in accord with a relatively sharp increase in P. pectinatus, and this modest reversal suggests that the latter species might have enhanced its competitive edge over the Characeae to a slight degree in this deepest part of the stream.

In a similar fashion, M. spicatum was more successful and more abundant than the Characeae (and the pondweeds) in the shallow NE and IE waters but with the charophytes becoming much more prevalent in the deeper IM to M sectors and with P. pectinatus developing slightly higher canopy cover levels than M. spicatum in the midstream location. Such adverse competitive effects of the Characeae on the abundance levels of M. spicatum and P. pectinatus can be additionally illustrated by comparing the station III data with that from Station II as follows:

Station III, in having high charophyte abundances, provided lower CC levels of M. spicatum and P. pectinatus than station II where the Characeae were largely insignificant, and the inter-station discrepancy in taxa prevalence was most distinct for P. pectinatus which was observed to be in more direct competition with the charophytes than the milfoils because of the pondweeds' and Characeae's more similar depth requirements. In addition, the CC levels of M. spicatum were actually somewhat greater at station III than at station II in the shallow E to IE sectors where the charophytes demonstrated low abundances in both of the reaches. But M. spicatum CC's were much lower at station III than at station II in the deeper IM to M sectors in concert with the marked downstream increase that occurred from station II to station III in the charophytic abundance levels of these three midstream locations.

As a further observation, the general non-prevalence of the Characeae at the two stations above the third appraisal site on the East Poplar is in accord with the comparatively shallow nature of these upstream segments, although other physical factors could also have been involved in retarding charophytic development in the two border reaches. For example, the border stations were dominated by a fine-grained substrate in comparison to the somewhat coarser bottom materials that were present in the station III channel. This downstream change to the coarser materials, along with the increasing depths, could have competitively favored the Characeae over the pondweeds and milfoils with the latter two taxa showing a greater success in the presence of the finer-grained substrates that were at the shallower upstream sites but with the charophytes not very competitive or successful under these up-river conditions. Whatever the case, numerous environmental features, including depth, substrate, and direct inter-taxa competition, undoubtedly played a role in defining the differing mixtures of floral composition and dominance that were noted for the various inventory locations within the Poplar basin.

Competitive Rankings of the Major Station Taxa. On a station basis, and in contrast to the flora at station II, the Characeae were observed to be more dominant and abundant than M. spicatum and P. pectinatus at the third appraisal site on the East Poplar as is shown by the charophyte's higher overall WCC percentage and distinctively high ABio value. However, M. spicatum was the most ubiquitous of any of the station III taxa, sporting the highest overall TCC and TF percentages, and P. richardsonii was also a fairly common species in the station III segment in view of its relatively high values for these same two variables. But P. richardsonii was not as successful a competitor as the other three dominants, and it was much less prominent in the stream as illustrated by its low WCC and ABio levels. The abundance pattern of P. richardsonii across the station III sectors was most closely meshed with that for M. spicatum, but M. spicatum was the most successful of the two species by a considerable margin as described by its much greater canopy cover percentages. The all-station competitive relationships of the dominant station III taxa can be capsulized as follows: Characeae > M. spicatum > P. pectinatus > P. richardsonii, with all of these plants having greater abundance levels than the subdominant sedges.

However, the competitive rankings of the above listed station III taxa were seen to differ to a considerable degree when specific positions and depths within the stream were reviewed instead of the plants' total CC ratings for the entire appraisal site. To provide for a general summary and illustration of these substation variations, the competitive ranking of P. richardsonii at station III with reference to the other three dominants and the major emergent, as based on CC, can be listed as follows for four different depth zones at the site: extremely shallow waters--Carex > P. richardsonii = M. spicatum > P. pectinatus > Characeae; shallow waters--M. spicatum > Characeae > P. richardsonii > Carex > P. pectinatus; moderately deep waters--Characeae > M. spicatum > P. pectinatus > P. richardsonii > Carex; and deep waters--Characeae > P. pectinatus > M. spicatum > P. richardsonii > Carex.

A comparison of the four abundance rankings of the dominant plants at station III for the different depths is generally illustrative of the distinct cross-stream floral variations that can be seen at most of the sampling stations, although the particular pattern will vary to a marked degree depending upon the site that is being reviewed. A few of the less conspicuous station III taxa (e.g., Poaceae and Zanichella) could also have been inserted into the above listings for one or two of the depth zones, but the five listed taxa were generally the most important components of the total station III flora in lieu of the other emergent, submersant, or amphibious forms that were recognized in this particular reach.

Community Characteristics

Abundance Rankings and Variations and Upstream Comparisons. One of the most distinctive vegetative features of the macrophyte community at station III (Table 17) was related to the sparse emergent association that was found along this reach with its relatively low weighted and true total ECC percentages in comparison to the other inventoried segments on the East Poplar River. This emergent plant grouping at station III was dominated by the inconspicuous and diminutive sedge and spike-rush forms, and the morphologies of these plants sharply contrasted with the plush bulrush and cat-tail stands that were observed along the two upstream portions of the stream. As a result, the emergent association at the third East Poplar station had only a sixth ranking in total ECC among the evaluated reaches, and it was one of the few appraisal sites in the survey where the submersant total CC and ABio values were significantly greater than the total CC and ABio values of the emergent plants.

The paucity of emergent growth at station III appears to be related to the comparatively pronounced depths of this particular stretch of the East Poplar (Table 11). Because of these typically deep waters, emergent CC, though somewhat prevalent in the shallow edge of water sector, demonstrated a marked decline to the IE sector with a complete absence of emergent tabulations from the deeper central parts of the stream. Furthermore, the third appraisal site demonstrated a relatively low edge of water emergent abundance in comparison to the higher E sector CC values of the other East Poplar stations. This feature, along with the total nudity of the three midstream sectors at station III with reference to the establishment of an out-of-water vegetation, also sets the station III reach apart from the more upstream locales, and these same characteristics serve to generally distinguish the station III plant community from the other aquatic communities that were examined along the East Poplar River.

Although the deep waters of the station III reach appear to have retarded the establishment of emergent plants in the segment, especially in the deeper sections of the river, these depths acted in an opposite fashion with respect to the submersant forms by greatly enhancing the development and growth of the underwater plants so that the third station on the East Poplar had the number one overall SCC ranking of any of the sites with its total weighted SCC value significantly greater (about 1.25-times) than that of the next highest ranked station (II). The submersant weedbeds at station III were most dense and pronounced toward the middle of the stream with a marked increase in SCC percentages from the shallow edge of water sector to the deeper NM location, although a slight drop in SCC did occur into the midstream sector as is the case for most of the Poplar locations. However, this high abundance of the underwater vegetation at station III did not act to totally offset the low canopy covers of the emergent association, and the station III segment, thereby, could only be given a third ranking among the sites on the basis of its total canopy cover percentages.

Emergent, Submersant, and Total Canopy Cover Relationships. For the most part, the Poplar stations that provided the highest total CC values tended to have a combination of relatively high emergent and submersant abundance levels, and this feature is illustrated by the number one total CC ranking of station II which was developed from the second and third rankings of its submersant and emergent associations. In contrast, stations that were dominated by high levels of either the emergent or submersant plants but with a low abundance of the counterpart association tended to have only a moderately high total CC percentage. Station III affords one example of this community characteristic in having an extremely high SCC rating but a low ECC value that produced a third total CC ranking among the stations. A different type of example along these same lines is seen in the station I data (Table 15) where its number one ECC rating in the face of a low SCC abundance produced only a fifth total canopy cover ranking for the drainage. Of course, the lowest canopy cover percentages of the basin were obtained from those stations where neither the emergent or the submersant abundance levels were very pronounced as will be shown for certain of the downstream appraisal sites.

In the main, it appears that the amount of submersant vegetation that was present at a sampling station played a somewhat larger role in relegating the relative magnitude of a segment's total CC levels than the general abundance of its emergent association. This observation is generally confirmed by the fact that the total CC rankings of the appraisal sites were more closely correlated with their submersant CC rankings ($r_s = 0.93$) than with their emergent CC rankings with a statistically significant but lower rank correlation coefficient ($r_s - 0.73$) obtained in the latter case. These relationships probably become evident in the inventory data because of the greater ecological space that was generally available in the study area waters for the ecesis of the submersant over the emergent forms with a greater maximum potential for developing high SCC percentages than for developing high emergent values. The occurrence of a high submersant space in the drainage is apparently related to a predominance of the deeper waters in the streams as a result of their ponded natures, and the deeper river segments would tend to enhance the expansion of a submersant association rather than a proliferation of the emergent plants. This trend was then largely culminated by the plant community at station III.

The total CC percentages of the station III sectors were relatively high all across the stream but with a general increase in this variable from a somewhat low edge of water reading to the highest values that occurred near the center of the reach. This change in total CC at station III paralleled the marked enhancement of submersant vegetation into the deeper waters, but the edge to middle increase in total CC was less pronounced than that for SCC because of the presence of some emergent plants in the shallow sectors along the banks of the river. The generally consistent cross-stream elevation of total CC at the third East Poplar inventory site was somewhat unique for the drainage, and it serves to additionally characterize this station vegetatively since the other appraisal segments demonstrated much more variable transverse changes in total plant cover with a general midstream decline being the most typical pattern for the study region. However, all of the sites, including station III, provided some type of drop in overall plant abundance towards the central part of the drainage course.

Diversity and Biomass Aspects. Along with providing a relatively high overall floral diversity with the recognition of seventeen plant groups, station III also exhibited a fairly pronounced transect point diversity (Taxa/Pt.) with an average tabulation of about one and three-fourths different taxa for each of the secondary lines. These point diversities were highest in the four edge to IM sectors, and they were most distinct at the ecotonal NE location. They then declined to some extent into the deeper near middle and middle sectors of the station, and such a general midstream decrease in the secondary line taxa tabulations was observed to occur at almost all of the sites. However, this drop was less distinct at station III than at most of the other sites with point diversities near the center of the stream tending to be generally higher at station III than they were near the center of the two upstream reaches. This inter-station difference was probably due to the mid-river mixing of four dominant and abundant submersant taxa at the third appraisal reach in contrast to the upstream dominance of only one or two of the submersant forms.

As described previously, the occurrence of the higher station III diversities in the sectors that were located closer to the shore was probably due to an inter-blending in this shallower part of the river of plants from both the diminutive near shore emergent association and the luxurious submersant association that was a prominent fixture of the central portion of the stream. This feature is further illustrated by the fact that eleven to thirteen emergent, submersant, and amphibious taxa were observed in the E and NE sectors of station III while only seven submersant taxa were identified from the middle part of the reach.

In opposition to diversity, the sector ABio values of station III demonstrated a consistent and marked increase from the diverse edge of water location that was dominated by the indistinct types of emergent plants to the more florally depauperate NM and M sectors that were dominated by the dense and vertically pronounced underwater stands of a few macrophytic taxa. Thus station III provides a prime example of the general inverse relationship that was observed between floral diversity and plant biomass through the up-drainage and deep-water portions of the study area. In correspondence with the high overall ABio value for the station, the low total TCC/WCC ratio (2.58) of the site is also indicative of high macrophytic biomass levels in the reach, and these biomasses were much more pronounced (about 1.7-times) with reference to the submersant vegetation (TCC/WCC = 2.44) than they were with reference to the emergent plants (TCC/WCC = 4.23).

General Physiognomy. The low total TCC/WCC ratio at station III in conjunction with the station's fairly high vegetative canopy cover percentage and low bare substrate frequency indicates that the plant community at the third appraisal site on the East Poplar, like the one at station II, had a dense weedbed-type of physiognomy that was most obvious in relation to the underwater association that was present in the deeper parts of the stream. In this instance, these submersant weedbeds were dominated by relatively thick growths of charophytic macroalgae and milfoil macrophytes with the varying transverse abundances of these taxa dependent upon the depth of a stream location. In addition, the pondweeds were also conspicuous components of these station III beds with the abundances of these plants again dependent upon the depth of a secondary line. Although the weedbed nature of the submersant association at station III was quite obvious, a different picture is developed with reference to the emergent plant grouping at this site.

Because of the comparatively high TCC/WCC ratio of the emergent plants at station III, and because of the high Veg. CC, plant density readings of the E to IE sectors at the site, the out-of-water association at station III provided a more carpet-like appearance in vegetative form instead of a totally weedbed-type of physiognomy. This carpet-like effect is due to a dominance of the reach by the non-distinct kinds of emergent taxa such as Carex and Eleocharis that have morphologies which afford a low biomass aspect. As a result, the station III emergent association was much less luxurious, less vertically pronounced, and somewhat more sparse than the emergent weedbeds or stands of Scirpus and Typha that were encountered at station II. However, both of these stream segments did contain distinctive weedbeds of underwater vegetation.

EAST POPLAR RIVER NORTH OF SCOBEY--STATION IV

Community Characteristics

Site Location and Physical Aspects. Station IV in the study region denotes a midway segment of the East Poplar River that is located about half-way between the international boundary and the confluence of the East and Middle Forks near Scobey, Montana to form the main Poplar River (Figure 1). This appraisal site was situated just downstream of the uppermost Highway 13 bridge in Montana about six miles south of the boundary and approximately four miles below the cluster of three stations that were placed in close proximity of the United States-Canadian border. Along with these upstream sites, this midway station on the East Poplar was surveyed in conjunction with the down-drainage station V and VI segments in order to obtain some insights into the downstream vegetational changes that probably occur within the river so that these observations can be used as a reference point with the advent of any subsequent macrophytic work that might be undertaken in the drainage in response to the Cookson impoundment. The background plant data that were obtained from this 556-foot middle-river inventory station as a result of the completion of this present survey are summarized in Table 18, and these data will form the basis for making any future, trend-related comparisons that might be required for the Poplar region.

Table 18. Summary of aquatic macrophyte data: East Poplar River north of Scobey (station IV).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E *Carex*	27.14	66.67	19.17	56.67	10.63	26.58	3.16	15.79	1.18	5.88	0.13	1.33	8.65	25.00	100.	3.46
E *Juncus*	0.95	9.52	0.17	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	1.25	14.3	1.00
E *Mentha*	0.24	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.25	4.8	1.00
E *Scirpus*	18.33	28.57	40.33	50.00	27.59	35.44	14.61	19.74	5.29	7.35	0.00	0.00	17.11	22.50	90.5	7.60
E *Typha*	0.24	2.38	0.00	0.00	0.13	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.50	9.5	1.00
E *Eleoch.*	15.48	59.52	5.00	23.33	0.51	5.06	1.84	9.21	0.15	1.47	0.00	0.00	2.85	12.75	90.5	2.24
S *Eleoch.*	0.00	0.00	0.00	0.00	0.25	2.53	1.32	3.95	0.29	2.94	0.00	0.00	0.35	1.75	19.0	2.00
E Poaceae	15.95	52.38	4.67	13.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.38	7.50	81.0	3.17
S Poaceae	0.00	0.00	0.00	0.00	0.00	0.00	0.13	1.32	0.00	0.00	0.00	0.00	0.03	0.25	4.8	1.00
E *Hipp.*	1.19	2.38	0.67	6.67	0.38	3.80	0.39	3.95	0.00	0.00	0.00	0.00	0.38	2.75	42.9	1.36
S *Hipp.*	0.00	0.00	0.00	0.00	0.25	2.53	0.13	1.32	0.00	0.00	0.00	0.00	0.08	0.75	9.5	1.00
E *Sag.*	0.00	0.00	0.00	0.00	0.13	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.25	4.8	1.00
S *Sag.*	0.00	0.00	0.17	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.25	4.8	1.00
E *Sparg.*	0.00	0.00	0.00	0.00	2.54	2.54	0.66	1.32	0.00	0.00	0.00	0.00	0.63	0.75	4.8	8.33
S *Sparg.*	0.00	0.00	0.00	0.00	0.63	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.25	4.8	5.00
S *Myr.*	0.00	0.00	6.17	33.33	22.53	64.56	44.47	82.90	64.56	95.59	51.33	89.33	34.43	66.50	100.	5.18
S *P. Pec.*	0.00	0.00	0.00	0.00	0.25	2.53	0.26	2.63	1.47	8.82	0.13	1.33	0.38	2.75	33.3	1.36
S *P. Ric.*	0.00	0.00	0.00	0.00	0.25	2.53	1.05	5.27	1.03	4.41	0.00	0.00	0.43	2.25	28.6	1.89
S *Zan.*	0.24	2.38	1.00	10.00	7.22	18.99	2.50	9.21	0.44	4.41	0.93	4.00	2.33	8.75	71.4	2.66
F. Algae	0.00	0.00	2.50	11.67	2.28	7.59	1.71	6.58	0.00	0.00	0.67	1.33	1.28	4.75	47.6	2.68
Total CC	79.76	226.19	79.83	208.33	75.57	178.48	72.24	163.16	74.41	130.88	53.20	97.33	71.63	161.75	--	4.43
E CC	79.52	223.81	70.00	151.67	41.90	75.95	20.66	50.00	6.62	14.71	0.13	1.33	32.20	73.50	--	4.38
S CC	0.24	2.38	9.83	56.67	33.67	102.53	51.58	113.16	67.79	116.18	53.07	96.00	39.43	88.25	--	4.47
Veg. CC	100.0	100.0	100.0	100.0	97.47	97.47	97.37	97.37	97.16	97.16	89.33	89.33	96.50	96.50	--	--
Bare Sub.	0.00	0.00	0.00	0.00	2.53	2.53	2.63	2.63	2.94	2.94	10.67	10.67	3.50	3.50	47.6	--
Bare-Alg.	0.00	0.00	0.00	0.00	2.53	2.53	3.95	3.95	2.94	2.94	10.67	10.67	3.75	3.75	--	--
ABio	--	3.53	--	3.83	--	4.23	--	4.43	--	5.69	--	5.47	--	4.43	--	--
Taxa/Pt.	--	2.26	--	2.08	--	1.83	--	1.68	--	1.35	--	1.09	--	1.68	--	--

The middle station IV reach on the East Poplar was somewhat distinct physically from the other Poplar sampling sites in the sense that it tended to assume the extreme features of a ponded segment. As a result, the physical attributes of this station were in almost direct opposition to the channel-like characteristics of the upstream border station (I) and the rapid-water features of the two downstream riffle sections.

The most distinctive physical aspect of the midway station was found in the marked width of the reach which corresponds to the practically negligible current velocities of the site (Table 12) with about 96% of the secondary lines producing no measureable current readings. Station IV, thereby, afforded the lowest current speeds of any of the sampled segments. But in spite of its pronounced width, this same reach provided only moderate depths that were much greater than those of station I and the riffles but less pronounced than the depths that were obtained from some of the narrower ponded locations(e.g., station II). Therefore, some vegetational differences might be anticipated for the station IV reach with reference to the other inventoried segments because of the midway station's particular combination of physical attributes, and the characteristics of the station's bottom materials should also be considered in this regard.

The mean substrate reference number of station IV was somewhat higher than the average index numbers of the three upstream segments (Table 13). However, these differences were due primarily to the relatively coarse materials that were encountered primarily in the middle sectors of the station IV reach with relatively low index values obtained from the station IV sectors that were located nearer to the shore. Thus, the station IV substrate reference numbers markedly increased from the bank to the center of the reach with the midstream sectors providing an unexpectedly high proportion of the coarse-grained bottom materials (Table 14). Such transverse changes in substrate composition were much more pronounced at this middle East Poplar site than they were at the other study stations.

Abundance Rankings and Upstream Comparisons. Station IV was somewhat distinct vegetatively from the three border appraisal sites on the East Poplar by having more nearly equivalent total SCC and total ECC levels than the upstream segments, and the total weighted SCC percentage of station IV was only slightly greater than that for ECC (about 12-times). This feature stands in contrast to the excessive emergent dominance of station I and the excessive submersant dominance of station III (and station II to some extent). Such a close E and S equivalence of the midway site was generally unique for the study area, and it was probably related to the moderate depths of this station in contrast to the much more shallow waters of station I and the deeper waters of station III. In addition, both the total emergent and the total submersant CC levels of the station IV reach were relatively high, ranked second and third respectively, so that the station also provided a fairly high total CC level for the basin with a second ranking in this regard among the different inventory sites.

As another community feature, the midway East Poplar segment, like the station II reach, also exhibited extremely high Veg. CC percentages with only a few of the secondary lines providing nonvegetated, bare substrate tabulations. This observation is suggestive of the occurrence of a dense aquatic vegetation that extends completely across a lotic channel. Thus station IV represents another East Poplar reach that had a distinctive hydrophytic plant community, and in this case, the underwater association was dominated by the milfoils to a major degree while the emergent grouping was largely dominated by the bulrush species.

In spite of the generally low current velocity readings at station IV, definite current tracks were observed in the thick submersant vegetation of the site where a series of Myriophyllum spicatum fronds were noticeably parted along a few undulating and obvious upstream-downstream paths that were scattered and interwoven throughout the underwater weedbeds of the reach. These current tracks were most plentiful near the center of the river in association with the greater velocities of the midstream locations. The bare substrate tabulations that were made at the station, thereby, were typically obtained in locations where the plants happened to be sufficiently parted at a secondary line so as to expose the presence of nonvegetated stream bottom materials at a small and centrally oriented selection of the transect points with the Bare Sub. percentage having its highest value in the middle sector of the station IV segment.

Abundance Variations and Depth Considerations. The emergent canopy cover percentages at station IV demonstrated a marked decline (near 100%) from the shallow edge of water sector to the deeper waters near the center of the stream. Although some emergent tabulations were taken from the near middle and middle sectors, unlike the case for station III, these were always obtained from a few shallow stream locations that just happened to correspond to the NM and M definitions because of the aberrant and skewed nature of the channel cross section on certain of the transect runs. However, a major proportion of the station IV NM and M secondary lines were evaluated in the deeper waters that were most characteristic of these stream locations, and since these deep-water points revealed the absence of emergent plants, the overall emergent CC levels of the two mid-river sectors were determined to be very low as shown in Table 18.

Furthermore, and in contrast to station I, emergent plants were not encountered entirely across the station IV reach on any of the primary transect lines because of the distinct depths that were eventually waded before completing a transect crossing. But the presence of some shallow water, plus the existence of some emergent vegetation in the central portion of the stream, was ultimately reflected in the somewhat low average depth values that were calculated for the NM and M sectors of the middle East Poplar appraisal site along with the occurrence of some low levels of ECC for this same middle section of the reach.

A vegetative-physical picture that is distinctively different from the one at station IV was painted by the station I reach as described previously. Such opposing inter-station differences in depth and vegetation coupled with the pronounced inverse relationships between depth and emergent CC that were calculated for station IV (r_s = -1.00) and some of the other ponded sites (e.g., station II) indicate that an excessive level of this physical variable acted as one of the major environmental factors in restricting the occurrence of emergent aquatic plants from the deeper lotic waters of the study region. Therefore, the generally moderate depths of station IV apparently allowed for the development of closely equivalent canopy covers between the emergent and the submersant associations, while the deeper waters at station III largely hampered an extensive establishment of the emergent forms in favor of the underwater vegetation. In contrast, the shallow waters of the station I reach were much more suitable for the growth of the emergent plants over the submersant taxa with depth, thereby, having a significantly different effect on the out-of-water associations than it had on the underwater species as outlined below.

The submersant vegetation at station IV demonstrated a marked increase in CC (near 100%) from the edge of water sector to the near middle sector of the reach with a slight drop then occurring to the middle of the stream as has been observed for some of the other Poplar appraisal sites. In contrast to the emergent association therefore, the submersant plants provided a statistically significant (at 1%) but positive rank correlation coefficient between average sector depth and SCC with $r_s = 0.94$ in this particular instance. These observations suggest that the shallow waters near the banks of the inventory streams were physically restrictive to the development of extensive underwater weedbeds, and the fully aquatic plants that were tabulated in these shallow water locations were typically observed to be the low-lying, diminutive, and sparse forms comprised of single taxa individuals or inconspicuous "springs" that were quite scattered and vertically indistinct in organization. But this depth restriction was largely lifted with the occurrence of the deeper waters toward the center of the ponded stream segments, and this physical change allowed for the growth of the vertically-pronounced, thick, and distinct submersant associations that were characteristic of the station IV reach and most of the East Poplar River.

Emergent-Submersant Canopy Cover Compensations. Although the SCC and ECC percentages of the six station IV sectors differed to a considerable extent within each of the series from sector to sector in response to a varying depth factor, their addition produced total sector CC values that were quite constant and consistent from stream location to stream location at the site with exception of a generally moderate drop in total CC from the NM sector to the center of the reach. Such an inter-sector constancy in total CC indicates that depth had a much less pronounced effect on the total canopy cover levels of the station IV reach than it had on the emergent and submersant components of the total expression. This feature stems from the fact that for any given sector, a depth-related deficit in the CC of one association was closely counterbalanced by a depth-related enhancement in the CC of the other plant grouping. This CC compensation was observed to be least complete at station IV for the midstream location, but such a middle sector deficit appears to be a characteristic of the entire study region rather than a unique feature of the station IV segment. In addition, the overall cross-stream ECC-SCC compensations of this kind were most complete at station IV with reference to the constancy of the station's inter-sector total CC values, and they were less obvious at the other appraisal sites which demonstrated much more variable inter-sector total CC levels.

For the most part, the emergent-submersant sector compensations of the stations were most complete, producing the lower inter-sector total CC variations, in those stream reaches having moderate depths, high plant abundances, close E-S equivalencies, and the less severe set of environmental factors. Thus stations II and IV, which demonstrated these required characteristics to a large extent, produced the greatest level of E-S compensation in having inter-sector total CC standard deviation/mean percentages in the vicinity of 13%. The other sites, however, which demonstrated greater deviations from these characteristics, produced percentages of this kind in excess of 21%. Stations III and VP, which provided a generally modest deviation from these required characteristics, had relatively low standard deviation/mean values of about 21%, while the riffle segments and stations I and VII, which provided a more distinct departure from the above listed requirements, afforded higher standard deviation/mean values between 28% and 42%. The extreme case was found in the ponded reach of station VI with a high standard deviation/mean percentage of 92% in response to the marked departure of this site from the features that are apparently needed to produce high levels of E-S compensation. In general therefore, it appears that the amount of inter-sector variation in the total canopy levels of a stream reach is largely reflective of the degree of environmental stress that is impinging upon the aquatic macrophyte community that is present within that drainage course. In the case of the Poplar basin, environmental stress was greatest at station VIP and least pronounced at stations II and IV, as suggested by these analyses.

Emergent-Submersant Competitive Relationships. In addition the direct and adverse physical effects of shallow water on the success of the submersant plants, the abundance of the emergent forms in these same shallow water locations probably acted to competitively retard the establishment and growth of the underwater taxa in these near shore locales. The negative influence of E-S biotic competition on the submersant plant group should then be largely eased in the deeper waters in accompaniment with the depth induced drop in emergent dominance that occurs through the midstream sectors, and this decline should contribute to the greater ecesis of the submersant forms in the deeper parts of the stream. But by the same token, the success of the submersant plants in the deeper midstream locations could have competitively retarded the establishment of the emergent taxa in these locales in concert with the unfavorable influence that excessive depths appear to have on these out-of-water forms.

Of course the magnitude of the opposing physical effects of depth on the emergent and submersant plants cannot be readily separated from the potential influences of emergent versus submersant competition, but the statistically significant and inverse rank correlation coefficient ($r_s = -0.94$) that was obtained between the ECC and SCC levels of the station IV sectors is suggestive of the occurrence of some degree of inter-association biotic competition between the underwater and out-of-water plants of the drainage. In general, the deeper waters tend to be restrictive to the emergent taxa but beneficial and competitively favorable to the underwater forms with the shallow waters tending to be restrictive to the submersant taxa but beneficial and competitively favorable to the emergent plants. As a result, both the biotic and the physical aspects of the inventory streams, including depth and numerous other environmental factors, probably acted together in some combination to define the distributional characteristics of the two broad plant groups across the station IV channel and across the other Poplar reaches.

Diversity and Biomass Aspects and General Physiognomy. The station IV Taxa/Pt. and ABio data in Table 18 provide another example of the inverse relationships that typically become evident between the floral point diversities of the sectors at a Poplar appraisal site and the sectors' plant biomass levels. The Taxa/Pt. values at station IV were relatively high in the shallow near shore waters with the total tabulation of nine to twelve different field-recognized taxa at this location and with the average tabulation of around two of these taxa for each of the secondary lines. Point diversities then demonstrated a marked decline to the midstream sector so that the middle section of the reach was almost mono-floristic in character. But in opposition to the Taxa/Pt. expressions, the sector ABio's significantly increased by a factor of about 1.6-times from the more diverse edge of water sector to the midstream location where exceedingly high plant biomass levels of a single taxon (Myriophyllum spicatum) were observed to be present in the stream.

The NM and M sector ABio's of the midway appraisal site were the highest that were recorded for any of the stations, and as a result, the total ABio of station IV can be rated as extremely high in relation to those of the other inventory segments. In addition, station IV exhibited extremely high levels of ABio for both the emergent and the submersant plants, and the close overall equivalence between the emergent and submersant associations with respect to this parameter, along with the close equivalence of the site's ECC and SCC percentages, also acts to set the midway stream reach apart from the other Poplar stations where the E and S balance was much less distinct (e.g., stations I and III).

In conjunction with these high E, S, and total community ABio readings, station IV also provided exceedingly low TCC/WCC ratios for the same three plant groupings with values of 2.28, 2.24, and 2.26 respectively. Such low ratios in association with the high Veg. CC percentages of the site are suggestive of the presence of a pronounced weedbed-type of community physiognomy that extends through both the dense emergent stands of aquatic vegetation that were found near the banks of the stream and the thick underwater plant aggregations that were encountered near the center of the channel. Thus the emergent association at station IV was distinctively different from the carpet-like out-of-water stands that were examined at the upstream station III reach on the East Poplar River.

Regardless of the high plant biomass levels of the station IV reach, this appraisal site revealed only a moderate station floral diversity with the field recognition of fourteen macrophyte taxa plus the floating algae component of the two algal groups, and this collection success stands in contrast to the field recognition of more than fifteen taxa at the upstream locations. In keeping with this observation, and in view of the statistically significant rank correlation that was obtained between the numbers of taxa at the stations and the stations' overall Taxa/Pt. values ($r_s = 0.69$), a generally moderate floral diversity was also exhibited by the middle East Poplar inventory site on the basis of its total Taxa/Pt. rating which can be assigned a fourth ranking among the evaluated segments. Because of this ranking, the station IV segment readily fits into a general sequence of downstream decline in macrophytic diversity that was observed to occur along the East Poplar River and the upper Poplar mainstem.

Floral Characteristics

Dominant Taxa and Upstream Comparisons. As indicated in Table 18, the four dominant taxa of the station IV reach can be listed as follows in a descending order of abundance: the submersant Myriophyllum spicatum species, the emergent Scirpus and Carex genera, and the amphibious Eleocharis genera. All four of these taxa were ubiquitous and highly prevalent floral components of the midway East Poplar segment as shown by their high TF and comparatively high true CC values, but Scirpus and M. spicatum were particularly conspicuous in the reach in view of their high WCC and ABio levels. These latter two plants, therefore, and particularly M. spicatum, made the major contributions to the distinctiveness and plushness of the pronounced aquatic weedbeds of the site, although the sedges and the spike-rushes were observed to be fairly common components of the emergent association that was present in the shallow, near shore waters. The bulrushes were most dominant in the slightly deeper offshore locations, while none of emergents were seen to be very abundant in the deep, midstream sectors of this middle station on the river.

In contrast to the somewhat diverse, shallow-water emergent association of the station IV reach with its high Taxa/Pt. values, M. spicatum totally dominated the deep-water, submersant weedbeds of the station which produced the comparatively low Taxa/Pt. values that tended to characterize this underwater association. And because of this excessive dominance of the milfoils, none of the other fully aquatic taxa were found to be overly abundant along the midway portion of the East Poplar River. The milfoils at this location demonstrated a marked cross-stream increase in canopy cover levels from the edge of water sector to the deeper central part of the reach that closely paralleled the cross-stream enhancement of the SCC levels of the station, and all of the emergent plants afforded an opposing decline in CC in this same direction in accord with the station's midstream drop in ECC. The four dominant taxa at station IV were also observed to be fairly abundant in either the shallow or the moderately deep waters, depending upon the plant's habit, of one or more of the upstream appraisal sites, but M. spicatum, Scirpus, and Carex actually achieved their greatest degree of prevalence in this middle segment of the river.

With reference to the entire Poplar study area, M. spicatum was identified in all of the inventory segments, and it was observed to be a highly abundant taxon at almost all of the sites. Both the Eleocharis and the Scirpus genera were also tabulated in nearly all of the inventory waters, but the spike-rushes, unlike the milfoils, typically afforded relatively low canopy cover levels across all of the stations. The bulrushes, in turn, were highly prevalent at a particular set of stations in the middle to upper portions of the East Poplar River, but they were generally inconspicuous at the remaining sites. Carex is probably best classified as being a somewhat prominent background plant in the drainage that was quite ubiquitous through all of the region but only moderately abundant at the sampling locations in contrast to the overall supra-dominance of the M. spicatum species.

Subdominant and Minor Taxa and Upstream Comparisons. The Poaceae and Zanichella can be categorized as subdominant and generally ubiquitous taxa in the station IV reach by having moderately high TCC and TF percentages. In addition, these two plants demonstrated somewhat high WCC and ABio values, and in the case of Zanichella, this latter feature is in accord with the general downstream increase in horned pondweed CC that was observed for the East Poplar River. Like Zanichella, the grasses were tabulated in low abundance at most of the Poplar sampling sites, and this taxa also achieved its greatest prevalence in the midway East Poplar reach. While the four dominant station IV taxa were found to be abundant in some of the upstream reaches, a number of the prominent taxa at the three border stations were observed to be either absent from the station IV waters (i.e., Characeae) or relatively inconspicuous components of the flora at the midway site (i.e., Typha, Sagittaria, Sparganium, Potamogeton pectinatus, and P. richardsonii). As a result, a fairly pronounced floral change did become evident in the East Poplar from its border segments to the middle section of the stream.

Along with the latter five taxa listed above, Juncus, Mentha arvensis, Hippuris vulgaris, and probably the floating algal group should also be added to a rare taxa listing for the station IV reach in light of their low CC, TF, and ABio values. However, M. arvensis and H. vulgaris, like Zanichella and Poaceae, were collected from a fair number of the Poplar sampling locations and can thereby be classified as generally ubiquitous plants with reference to the entire drainage, but these first two species were typically observed to be present in very low abundance levels. Contrariwise, Juncus, like Heteranthera dubia, was identified as both a non-abundant and a non-ubiquitous plant in the basin by being tabulated in low canopy cover levels at only two of the appraisal segments that were surveyed during the study.

General Physical Requirements of the Water-Milfoils. The most distinctive floral-vegetative characteristic of the station IV reach probably resides in the pronounced dominance of Myriophyllum spicatum in relation to the other station taxa with the milfoils providing 48% of the total WCC levels of the reach and 87% of the overall WCC levels of the submersant association. In contrast, the most prevalent plant at the other stations, including M. spicatum in some of the cases, afforded less than 38% of the total station WCC of the site and less than 50% of the overall WCC levels of the corresponding emergent or submersant plant grouping. Therefore, station IV tends to stand out from the other appraisal sites because of the severity of the top-taxa dominance in this one particular Poplar reach.

The extreme dominance of the milfoils at station IV suggests that the particular blend of water depth, current velocity, and substrate type in the stream segment was highly and uniquely suitable to the establishment, growth, and proliferation of this one underwater plant species so that it becomes competitively successful in this midway reach to a marked degree over the other submersant plants of the drainage. Conversely, the physical aspects of the station IV segment do not appear to be very conducive to the ecesis and competitive success of the non-milfoil taxa that were observed to be abundant at some of the upstream locations (e.g., the charophytes, Potamogeton pectinatus, and P. richardsonii) but non-abundant in this middle part of the East Poplar River.

The physical requirements of M. spicatum can be generally deduced by determining the physical attributes of those upstream station sectors at which the milfoils demonstrated high canopy cover levels. These physical characteristics can then be referenced to the depth, velocity, and substrate features of the station IV reach to see if an appropriate correspondence exists between the two comparatives, and the actuality of a close correspondence in this regard then serves as a check for assessing the physical needs of this underwater species. In the main, the milfoils were most expressive in the two intermediate sectors of the upstream sites with these locations having moderate depths, low current speeds, and typically fine-grained substrate compositions. Station IV, in turn, can be characterized by its moderate depths, low current velocities, and by its fine-grained bottom materials in the shallower intermediate waters so that the two comparatives do happen to closely coincide.

As a further observation, the drop in milfoil canopy cover from the NM to the M sector at station IV corresponded to a fairly pronounced increase in the magnitude of the three physical variables across these same two sectors, and the low abundance of the plant in the E and NE sectors corresponded to the shallow nature of the waters that were found near the banks of the stream. Thus, the physical aspects of the midstream and near shore locations of the station IV segment appear to be less than ideal for the development of high levels of milfoil growth in comparison to the more amenable physical attributes of the intermediate sections of the reach. But for the most part, these comparative evaluations do suggest that the physical nature of the midway segment on the East Poplar River was highly appropriate for the establishment, success, and dominance of M. spicatum with reference to the projected physical demands of this one submersant species. To achieve a maximum development therefore, the milfoils apparently require moderate stream depths in the vicinity of 1.0 to 1.6 feet, low current speeds that are less than about 0.03 feet per second (fps), and a wide-ranging bottom material composition that provides for substrate index numbers somewhat greater than 1.0 units but typically less than 2.0 units.

Specific Requirements of the Water Milfoils: Assessment Approach. In support of the above discussion, the physical needs of M. spicatum can be described more specifically by mathematically determining a milfoil-WCC weighted average depth value for the plant, a current velocity value of this kind, and a weighted mean substrate reference number. The physical and WCC data base for making these calculations was obtained from the ten stream sectors at which M. spicatum was found to be the most abundant through all of the appraisal sites. Sectors with such high milfoil CC's were uncovered at four of the stations (II to V), and these high abundance sectors were chosen for use in this kind of manipulation in order to obtain a best estimate of the optimum depth, current velocity, and substrate type that might be required by the taxon so as to achieve its greatest growth potential within the confining limits of the Poplar system.

If one or more of these three physical factors at any given stream location should happen to provide a value that is much above or below the optimum for M. spicatum, then this plant would not be expected to be very prevalent at that same location within the stream. But if all three of the physical factors should happen to afford values that are in a fairly close proximity to the optimums that were established for the milfoils, then a high level of abundance and competitive success might be anticipated for this taxon in that particular section of the stream.

As will be shown in the next sections of this report, the same line of reasoning that was directed to M. spicatum can also be applied to the other drainage taxa with reference to their specific optimum values for the three physical features. In general, the relative magnitude of the CC level of a taxon in any of the stream reaches should be inversely related to the degree of deviation of the segments' physical measurements from the optimums that might be required by any of the plants. That is, the higher abundances might be anticipated in those locations where this discrepancy was relatively low. However, the actuality of this relationship is highly contingent upon the assumption that the other potential affecting factors that are not being considered were largely non-influential within the system, and this assumption includes the accessory aspect of a direct biotic competition for space and other environmental necessities that was probably operating within the Poplar waters among the different macrophytic plants.

Water-Milfoil Evaluations. The optimum depth (D), current velocity (V), and substrate index (S) values that were calculated for M. spicatum following the above described guidelines can be listed as follows: D = 1.42 feet, V = 0.016 fps, and S = 1.67 units. These numbers fall within the depth, velocity, and substrate index ranges that were listed previously for this taxa as derived from the more general physical analysis. Also, the above numbers closely coincide with the depths, velocities, and types of substrate that were measured for the station IV sectors where the water-milfoils were highly abundant with these intermediate sectors having depths between 1.0 and 1.8 feet, velocities between 0.0 and 0.02 fps, and substrate index ratings typically between 1.1 and 2.25 units. The results of these physical comparisons, therefore, further explain the "why's and the wherefore's" of the extremely high abundance levels of M. spicatum in the station IV reach (Table 18).

As a further evaluation, the physical characteristics of the station I segment were found to be quite different from the optimum physical requirements of the milfoils with the station I reach having distinctly shallower depths (typically less than 0.8 feet), greater current speeds (generally well in excess of 0.02 fps), and finer-grained bottom materials (substrate index numbers usually less than 1.7 units). The physical deviations of the station I section from the optimum depth, velocity, and substrate values that appear to be required by M. spicatum in the Poplar drainage is in accord with markedly low abundance levels of the milfoils in this border reach of the East Poplar River (Table 15) in relation to the much higher canopy covers that were tabulated for the taxon in the more amenable midway East Poplar segment. Thus, this type of physical assessment is also explanatory for the lack of prevalence of M. spicatum in a particular Poplar reach because of the segment's physical inadequacies as well as accounting for its high abundance levels in some of the basin waters which had a more suitable set of physical attributes.

Specific Requirements of the Major Emergent Taxa: Overview. Following the above described calculative methodology, optimum depth, velocity, and substrate index unit values were also determined for the five major emergent taxa at station IV and the three upstream sampling sites. The results of this analysis with depth in feet and velocity in fps can be listed as follows: Carex--D = 0.39, V = 0.006, and S = 1.86; Eleocharis--D = 0.27, V = 0.006, and S = 1.63; Sagittaria--D = 0.66, V = 0.101, and S = 1.32; Scirpus--D = 0.64, V = 0.007, and S = 1.16; and Typha--D = 0.99, V = 0.030, and S = 1.02. The findings from similar evaluations that were applied to the major submersant taxa of the East Poplar River, in addition to those that were directed to M. spicatum, will be presented below.

These optimum emergent taxa values for water depth, current velocity, and substrate type were typically significantly lower than the averages of these physical variables for all of the appraisal sites: D = 0.94 feet, V = 0.079 fps, and S = 2.48 units. Such differences between a taxon optimum and a basin average suggest that there was a definite tendency among the out-of-water plants of the basin for achieving a high abundance in particular stream locations that had a certain set of appropriate physical features. This stands in contrast to the case of a random or even distribution of taxon abundance through all of the stream sectors of the drainage which would have pointed to a general inaction of the three physical factors since the optimum taxa values in this instance would have been more similar among themselves and more akin to the basin means of the three non-biotic variables rather than providing the distinct differences that were actually observed in the survey. Thus, the emergent plants of the study region did appear to be definitely curtailed in some of the Poplar waters by the negative influences of excessive depth, current velocity, and coarse substrate compositions, although the plants were enhanced in those stream locations that had the necessary mixture of these physical factors.

Because of these constraints, the optimum physical values listed above indicate that the emergent taxa, like the milfoils, were generally most abundant in stream sectors having low current speeds that were well below the basin mean. However, the emergent plants were unlike M. spicatum in requiring shallower waters than the average for achieving a maximum development, and this feature might be expected for aquatic plants having this type of growth habit with these taxa found to be most prevalent in a closer vicinity of the banks of the streams. The emergents also required the presence of a relatively fine-grained bottom material in order to establish a high level of abundance, but a fair degree of variation did become evident among these plants in terms of their specific optimum index number.

Emergent Taxa Evaluations. Sagittaria tended to stand out to some extent from the other out-of-water plants by requiring a higher than average current speed along with a moderately shallow water and a relatively fine-grained substrate for its maximum establishment in the streams. In response, the combination of appropriate water depths, rapid current velocities, and fine-grained bottom compositions in the station I reach corresponded to the high canopy covers of the arrowheads in this one segment of the drainage. The prevalence of Sagittaria then markedly declined downstream on the East Poplar in conjunction with the greater depths, slower current speeds, and coarser substrates that seemed to characterize most of the down-drainage segments.

Along with Sagittaria, Typha latifolia was also a distinct taxon among the emergent plants by requiring a comparatively deep water and an extremely fine-grained bottom material for its maximum development. This strict substrate requirement accounted for the narrow distribution of the cat-tails to stations II and IV in the Poplar basin since the substrate reference numbers of the near shore locales at many of the sampling stations were typically much greater than the substrate optimum if *T. latifolia*. Furthermore, the greater optimum depth value of *Typha* with respect to *Scirpus* was reflected in the greater abundance of the first taxa over the second in the deeper waters of the station II segment (e.g., the IE sector) in contrast to the greater prevalence of the bulrushes over the cat-tails in the near shore waters of the second appraisal site (e.g., the E sector). As a further factor, the higher substrate optimums of the bulrushes allowed for a wider distribution of this plant through the study region than what was noted for the cat-tails. However, the abundance levels of *Scirpus* in certain parts of the basin were restricted to a significant extent because of the occurrence in otherwise suitable stream sectors of coarse bottom materials that were well above the taxon's optimum for this variable.

Like the *Scirpus*-*Typha* depth comparison of station II, a similar relationship also existed among the *Carex*, *Eleocharis*, and *Scirpus* genera of the plant community at station IV. In this case, the bulrushes with their greater depth requirements were dominant in the deeper NE and IE sectors of the site but with the *Carex*-*Eleocharis* (and Poaceae) group more abundant in the shallow E sector in accord with the reduced depth optimums of these latter plants. Furthermore, *Eleocharis* (and Poaceae) demonstrated a more pronounced decline in canopy cover than *Carex* from the E to the deeper NE sector of the station IV reach in conjunction with the spike-rushes' lower depth needs. In the main, the emergent *Carex*-*Eleocharis* genera were generally restricted to shallower waters than the bulrushes with the latter taxon observed to occur in both the extremely shallow and the moderately shallow sections of the streams.

In addition to depth, the differing substrate optimums of the *Carex*-*Eleocharis*-*Scirpus* emergents were also contributing factors to the varying abundance-distribution patterns of these three taxa in the Poplar drainage. That is, *Scirpus* was relatively rare or absent in the presence of the coarser-grained substrates having index values greater than about 1.3 units, while the sedges and spike-rushes were dominant in the near shore locations of these coarse-grained stations (III and V to VII). But the bulrushes tended to dominate the emergent associations of those appraisal sites exhibiting a fine-grained bottom material in the near shore locales with *Carex* and *Eleocharis* present and fairly abundant but typically non-dominant at these kinds of stations (I, II, and IV). Such distributional differences, in turn, are in accord with the higher substrate optimums that were calculated for *Carex* and *Eleocharis* over the lower optimum that was recorded for the bulrush species.

Specific Requirements of the Major Submersant Taxa: Overview. The optimum depth, velocity, and substrate index values that were calculated for the major submersant taxa in the East Poplar River can be listed as follows with the data for *Myriophyllum spicatum* again included for comparative purposes: Characeae--D = 1.79, V = 0.050, and S = 1.74; *M. spicatum*--D = 1.42, V = 0.016, and S = 1.67; *Potamogeton pectinatus*--D = 1.61, V = 0.091, and S = 1.48; *P. richardsonii*--D = 1.44, V = 0.029, and S = 1.40; and *Sagittaria*--D = 0.67, V = 0.131, and S = 1.40. Similar to the emergent optimums, the physical optimums for the submersant taxa were generally different from the basin means of these three variables, and this feature also suggests that the distributions and abundances of the underwater plants in the Poplar drainage were affected by the changing inter-reach influences of water depth, current speed, and substrate type as has been noted for the emergent forms.

As indicated by the above optimum value listing, the major submersant taxa required greater than average depths and much deeper waters than the emergents for the development of a high canopy cover level in the Poplar basin. Like the out-of-water plants however, the submersants were also most successful in the presence of a relatively fine-grained bottom material, although a slightly coarse composition, i.e., a sand and silt mixture, was found to be more preferable to the underwater plants than a pure muck substrate. But in the more extreme case, the overall canopy covers of both the submersant and the emergent associations as well as the total CC levels of some of the station segments were observed to be comparatively low in the face of these sites' much coarser sand-gravel to rock substrate mixtures that had mean index numbers greater than about 2.0 units. Since the submersants also fared best under the low to moderately low current velocities of the drainage, these plants, thereby, demonstrated their highest canopy covers in those stream segments describing a ponded form of morphometry in association with a fairly low substrate index value (e.g., stations II to IV). Conversely, the submersant taxa were not very prevalent in the channel-like station I segment with its shallow waters and its rapid current speeds.

Submersant Taxa Evaluations and Interference from Biotic Competition. The submersant taxa also demonstrated some degree of variation among themselves with reference to their optimum depth, velocity, and substrate values within the confines of the Poplar system, and to a large extent, these optimum variations coincided with the differing physical attributes of the stream reaches and the different types of distributional and abundance patterns that were demonstrated by these underwater plants through the Poplar waters. The physical reasons for the marked prevalence of M. spicatum at station IV in view of the milfoils' optimum values have been described previously, and three other obvious examples of such interrelationships can be briefly outlined as follows:

In the first case, the dominance of P. pectinatus over M. spicatum in the central part of the station II reach (Table 16) corresponded to the moderate depths and somewhat rapid current velocities of these sectors in accordance with the pondweed's requirements, while the dominance of M. spicatum over P. pectinatus in the intermediate portions of the station II segment corresponded with the slower current speeds of these locations as required by the milfoils. A similar relationship between these same two taxa is also evident in the station III data. In the second example, the marked dominance of the Characeae over the other submersant plants in the midstream parts of the station III reach (Table 17) was in accord with the IM to M sectors' pronounced depths, moderately low current velocities, and somewhat coarse substrate compositions. These features generally coincided with the optimum physical values of the stoneworts, and M. spicatum, thereby, was dominant over the Characeae in the E to IE sectors of station III with their shallower waters and less rapid current speeds.

As a third example, the prevalence of submersant Sagittaria in the station I reach (Table 15) corresponded with the segment's shallow depths, comparatively fast currents, and fine-grained substrate compositions with these features matching the optimum physical values that were presented by the arrowheads. These plants, in turn, were inconspicuous components of the deeper and less currented ponded reaches of the study area, and they were largely absent from those segments having the coarsegrained bottom materials.

Both the emergent and the submersant variations of Sagittaria had similar depth and substrate requirements, although the underwater component did demonstrate a higher current proclivity than the out-of-water phase of the plant. This feature suggests that the presence of a high current velocity tended to "force" the arrowheads to assume an underwater habit to a greater extent in the fast water locales over what was observed to be "normal" for the taxon. Otherwise, variations in depth and substrate did not appear to act as a mechanism for defining the emergent and submersant aspects of the plant in favor of a different set of operating factors, and one or the other of the two arrowhead morphologies were then sporadically encountered in the less currented stretches of the reach when making the transect runs. But as indicated in Table 15, the emergent phase of Sagittaria, representing the primary growth form of the plant, was tabulated more frequently than the submersant stage. As another option for explaining the occasion of the less frequent submersant arrowhead tabulations, some of the emergent Sagittaria vegetation could have died back at some time during the course of the inventory to leave only the residual submersant plant parts, and these residuals would have been subsequently counted as an underwater plant on the survey data sheets.

In addition to the above examples, a number of other interrelationships involving the physical optimums of the many aquatic taxa, the physical characteristics of the stream reaches, and the distribution and abundance of the plants through the study segments can be identified in the refined inventory data for both the emergent and submersant forms. Some of these were quite subtle in nature, and additional discussions and a detailed cataloging of these specific aspects of the Poplar basin's aquatic vegetation are beyond the scope of this present report. However, the above descriptions do provide excellent vignettes of the physical requirements, optimum physical value variations, and instream interrelationships that were uncovered for several of the most important plant taxa in the upper Poplar River drainage.

As an appended comment along these lines, the action of inter-taxa competition should be kept in mind in all of the cases where the physical and abundance-distribution interrelationships of the study area plants are being reviewed because of the penchant of this biotic factor for potentially skewing the optimum physical values of the taxa to some extent. That is, a highly competitive taxon that is constrained by a relatively narrow physical requirement could cause another less competitive form with a wider ecological amplitude to be most prevalent but generally non-abundant through a non-optimum physical range even though the second plant would be much more successful within the physical limits of the first plant's requirements given the absence of this more competitive representative from the system. But in spite of the potential for such biotic interactions to alter the true optimum physical values of a taxon, the estimated optimums that were calculated in this survey for depth, velocity, and substrate do provide some insights into the physical environs where a major Poplar taxon was most successful within the context of the survey region and within the region's particular intermingling of biotic competition among and between its emergent and submersant aquatic plants.

EAST POPLAR RIVER NEAR SCOBEY--STATION V

Floral Characteristics of the Riffle and Ponded Segments

Site Location. In addition to the four appraisal sites that were described previously, a fifth inventory station was placed on the lower part of the East Poplar River in order to secure information that would help to additionally define the downstream floral and vegetational changes that probably occur in the river. This lower station was situated about three miles north of Scobey, Montana and about six miles below the midway site on the East Poplar (Figure 1), and it was located about one mile above the confluence of the East and Middle Forks to form the upper Poplar mainstem. A ponded segment largely dominated this lower reach, but unlike the upstream sites, a short riffle section was also found in a close proximity of the station access point. This riffle segment was then inventoried so as to enhance the comparative applications of the project's data base. The plant data that were obtained from the riffle component of the appraisal site are presented in Table 19 (VR), and the plant data that were secured from the ponded portion of the station V reach are summarized in Table 20 (VP).

Physical Aspects. The ponded portion of the station V reach provided the typical thirty- to forty-foot widths, the relatively pronounced depths, and the generally reduced current speeds that tended to define this type of stream morphometry within the Poplar River drainage. But regardless of the nondistinctive nature of the pool's average depths at station V, a distinctive physical feature was identified in the station VP segment in terms of the marked maximum depth values (Table 11) that were measured at some of the secondary lines in the IE to M sectors of the appraisal site. These maximums were significantly greater than those that were obtained from the other ponded reaches of the study area.

In addition to the high maximum depths, station VP also provided for larger substrate reference numbers than the upstream sites (Table 13), and notably coarser-grained bottom materials were observed in almost all of the VP inventory sectors (Table 14). As suggested by the earlier discussions, such discrepancies in substrate composition between the station VP reach and the upstream sites would be expected to be reflected in the occurrence of some vegetational differences between the plant community of the lower East Poplar and the communities of the midway and upper portions of the river. But because of the smaller inter-station variations, the current velocity- and depth-related vegetational differences of this kind would not be expected to be as pronounced. Similar to the upstream stations, station VP demonstrated an increase in its substrate index values and an increase in its stream depths from the near shore to the midstream locations with the coarsest substrates encountered near the center of the segment in accord with the higher current velocities that were measured in these more central positions of the stream. Therefore, some cross-stream vegetational changes might also be anticipated for station VP as a result of these transverse physical alterations.

The relatively narrow riffle segment at station V provided a distinctively different assortment of physical characteristics than the ponded reach at this same location and the pools of the three upstream sites.

Table 19. Summary of aquatic macrophyte data: East Poplar River near Scobey (station V-*riffle*).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E *Carex*	22.22	66.67	10.77	46.15	3.33	14.29	0.48	4.76	0.00	0.00	0.00	0.00	5.39	19.13	88.9	2.82
E *Mentha*	0.56	5.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.87	11.1	1.00
E *Scirpus*	0.56	5.56	1.54	15.38	0.48	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.35	3.48	22.2	1.00
E *Eleoch*.	4.44	22.22	3.85	7.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	4.35	44.4	2.60
S *Myr*.	0.00	0.00	6.15	30.77	6.67	47.62	12.38	47.62	2.50	25.00	3.18	13.64	5.22	27.83	77.8	1.88
S *P. fil*.	0.00	0.00	0.00	0.00	0.00	0.00	0.48	4.76	1.00	10.00	0.00	0.00	0.26	2.61	22.2	1.00
S *P. fol*.	0.00	0.00	0.00	0.00	0.48	4.76	0.48	4.76	2.50	5.00	2.27	4.55	1.04	3.48	33.3	3.00
S *P. pec*.	0.00	0.00	0.77	7.69	4.76	28.57	3.33	14.29	3.50	15.00	3.64	18.18	2.87	14.78	44.4	1.94
B. Algae	0.56	5.56	9.23	30.77	0.95	9.52	3.81	19.05	8.00	40.00	1.82	18.18	3.74	20.00	100.	1.87
F. Algae	1.11	11.11	3.85	7.69	0.48	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.70	3.48	22.2	2.00
Total CC	29.44	116.67	36.15	146.15	17.14	114.29	20.95	95.24	17.50	95.00	10.91	54.55	20.78	100.00	--	2.08
E CC	27.78	100.00	16.15	69.23	3.81	19.05	0.48	4.76	0.00	0.00	0.00	0.00	6.96	27.83	--	2.50
S CC	1.67	16.67	20.00	76.92	13.33	95.24	20.48	90.48	17.50	95.00	10.91	54.55	13.83	72.17	--	1.92
Veg. CC	72.22	72.22	84.62	84.62	66.67	66.67	71.43	71.43	70.00	70.00	50.00	50.00	67.83	67.83	--	--
Bare Sub.	27.78	27.78	15.38	15.38	33.33	33.33	28.57	28.57	30.00	30.00	50.00	50.00	32.17	32.17	100.	--
Bare-Alg.	33.33	33.33	23.08	23.08	33.33	33.33	38.10	38.10	65.00	65.00	68.18	68.18	47.83	47.83	--	--
ABio	--	2.52	--	2.47	--	1.50	--	2.20	--	1.84	--	2.00	--	2.08	--	--
Taxa/Pt.	--	1.62	--	1.73	--	1.71	--	1.33	--	1.36	--	1.09	--	1.47	--	--

Table 20. Summary of aquatic macrophyte data: East Poplar River near Scobey (station V-*pool*).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E *Carex*	28.50	75.00	16.56	54.10	4.48	13.43	0.29	2.90	0.00	0.00	0.00	0.00	6.77	20.27	100.	3.34
E *Mentha*	0.75	7.50	0.16	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.27	20.0	1.00
E *Scirpus*	0.25	2.50	0.49	4.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	1.10	10.0	1.00
E *Eleoch.*	16.50	45.00	10.66	27.87	1.04	4.48	0.00	0.00	0.00	0.00	0.00	0.00	3.78	10.41	90.0	3.63
E Poaceae	0.50	5.00	0.82	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.82	10.0	2.33
E *Hipp.*	3.00	20.00	1.31	6.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	3.29	50.0	1.67
S *Hipp.*	0.00	0.00	0.98	3.28	0.30	2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.22	1.10	20.0	2.00
S *Sag.*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.41	0.03	0.27	5.0	1.00
S *Char.*	0.00	0.00	0.49	4.92	7.16	23.88	8.12	20.29	6.49	12.28	6.62	11.27	5.23	13.15	50.0	3.98
S *Myr.*	0.25	2.50	12.62	44.26	17.76	56.72	19.13	53.62	15.78	56.14	9.44	28.17	13.32	42.47	100.	3.14
S *P. fil.*	0.00	0.-0	0.33	3.28	0.60	5.97	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.64	20.0	1.00
S *P. fol.*	0.00	0.00	0.33	3.28	0.15	1.49	0.43	4.35	0.00	0.00	0.00	0.00	0.16	1.64	20.0	1.00
S *P. pec.*	1.25	2.50	1.64	9.84	12.84	35.82	14.49	36.23	9.82	24.56	12.54	28.17	9.48	24.66	90.0	3.84
S *Zan.*	0.25	2.50	1.80	3.28	1.64	2.99	0.29	2.90	0.00	0.00	0.00	0.00	0.68	1.92	10.0	3.57
B. Algae	0.00	0.00	0.33	3.28	0.90	2.99	2.46	7.25	0.88	1.75	0.85	2.82	0.99	3.29	35.0	3.00
E. Algae	1.50	15.00	6.07	32.78	6.87	20.90	6.52	15.94	2.81	5.26	4.37	7.04	4.96	16.16	85.0	3.07
Total CC	52.75	177.50	54.59	204.92	53.73	171.64	51.74	143.48	35.79	100.00	33.94	78.87	46.74	143.29	--	3.26
E CC	49.50	155.00	130.00	96.72	5.52	17.91	0.29	2.90	0.00	0.00	0.00	0.00	11.51	36.99	--	3.11
S CC	3.25	22.50	24.59	108.20	48.21	153.73	51.45	140.58	35.79	100.00	33.94	78.87	35.23	106.30	--	3.31
Veg. CC	92.50	92.50	90.16	90.16	89.55	89.55	81.16	81.16	68.42	68.42	52.11	52.11	77.81	77.81	--	--
Bare Sub.	7.50	7.50	9.84	9.84	10.45	10.45	18.84	18.84	31.58	31.58	47.89	47.89	22.19	22.19	90.0	--
Bare-Alg.	12.50	12.50	9.84	9.84	10.45	10.45	21.74	21.74	33.33	33.33	47.89	47.89	23.56	23.56	--	--
ABio	--	2.97	--	2.66	--	3.13	--	3.61	--	3.58	--	4.30	--	3.26	--	--
Taxa/Pt.	--	1.92	--	2.27	--	1.92	--	1.77	--	1.46	--	1.51	--	1.84	--	--

These physical differences can be summarized as follows: The riffles demonstrated much shallower average and maximum depths than the pools across the NE to M sectors of a stream cross section; the riffles also afforded much more rapid current velocities than the ponded waters through these same five sectors plus the E sector of station V; and the riffles revealed coarser substrate compositions than the pools in almost all of the possible interstation and intra-station comparisons. In fact, station VR presented the coarsest overall bottom materials of any of the sites, and it had the highest single substrate index rating (the middle sector) of any of the stream locations that were examined during the project. As a result of these features, the station V riffle segment, and this type of stream morphometry in general, described a much harsher environment for the establishment and growth of aquatic plants than most of the ponded reaches, and marked differences in vegetation should thereby become evident between the short and scattered riffle segments of the upper Poplar drainage and the long and expansive ponded reaches that were inventoried along the East Poplar River.

The environmental harshness of the riffle-type of stream morphometry with reference to the macrophytic plants was augmented in a midstream direction at station VR because of the increases in substrate coarseness and current velocity that occurred from the E to the M sectors of the reach. The station VR depths also showed a slight increase in magnitude in this same direction with this depth enhancement expected to favor the submersant plants while detracting from the emergent forms. However, such depth influences would appear to be quite minor in view of the narrow range of shallow depths that were found in the riffled part of the Poplar streams.

In the main, the rapid current speeds and coarse substrates of the riffles should act to severely retard the establishment of the emergent plants, while the shallow depths, coarse substrates, and to a lesser extent, the swift waters of these segments should act to curtail the development of the submersant forms in these particular sections of the drainage. The rough-grained substrates at station VR were somewhat similar to, though more pronounced than, the coarse bottom materials that were found in the ponded station V section and in the central part of the midway station IV reach, and they were definitely dissimilar from the finer substrates that were encountered as the upstream border sites. The rapid current speeds and shallow waters of the riffles, in turn, were most akin to the channel-like qualities of the station I segment. Thus, the comparatively low plant abundances of this border station should serve as a portent of the low plant canopy covers that might be anticipated for station VR and the other riffle segments, and the coarse substrates of these locations should additionally detract from the potential for macrophyte growth in these riffled stretches of the streams.

As a separate and miscellaneous observation, an integrated stream flow for the three sampling trips to the study area was determined for the station VR segment by using the refined physical data that were taken from the site--the average width of the reach split into 20% parcels plus the corresponding mean depth and mean current velocity numbers of the five instream station sectors. An East Poplar discharge for the sampling period was calculated in this fashion at 2.4 cubic feet per second (cfs), and this value generally falls within the range of warm weather East Poplar flows that were measured at the two formal gaging locations on the river--one upstream at the international boundary, and the other downstream on the river near Scobey, Montana (USGS, 1975-1979). The mean daily warm weather USGS flows at these two locations typically varied from 1.5 cfs to 4.0 cfs, and the general correspondence between these USGS values and the station VR flow that was estimated from this study's physical data tends to confirm the validity of the physical measurements that were made as a part of the macrophyte survey project.

Intra-Station Segment Comparisons: General Taxa Compositions. As indicated in Tables 19 and 20, eight macrophytic taxa plus the two algal groups and thirteen macrophytic taxa plus the two algal groups were recognized for a riffle or ponded section of station V respectively. Thus, the riffle segment demonstrated a lower floral diversity than the ponded reach in response to the less harsh physical environment that was found in the latter stream location. But in spite of these differences in floral diversity and the marked physical differences that became evident between the two station V components, these two segments did demonstrate fairly close and surprisingly similar taxa compositions since all of the taxa that were recognized in the riffle segment were also spotted in the ponded reach.

One of the major floristic differences identified for the two station V segments revolved around the observation that five of the taxa tabulated from the pools could not be uncovered in the riffle section (Characeae, Poaceae, Hippuris vulgaris, Sagittaria, and Zanichella palustris) which accounts for the riffle's lower plant diversity levels. However, the latter four riffle-restricted taxa were found to be inconspicuous floral representatives of the ponded reach with generally low CC, TF, and ABio values so that the inter-segment floral discrepancies on this basis were actually not all that pronounced. Furthermore, the absence of the stoneworts from the shallow riffles and their abundance in the much deeper pools was in accord with the relatively deep depth requirements of these macrophytic algae.

In addition to the four minor taxa listed above, Mentha arvensis, Scirpus, Potamogeton filiformis, and P. foliosus were observed to be relatively unimportant taxa in both of the station V reaches. Of these, P. foliosus was unique for the study area in being found in low abundance levels primarily in the lower East Poplar River and in the Middle Fork in association with the reduced CC levels and the coarse bottom substrates of these particular waters. Also, either the floating algae or the bottom algae can be rated as an inconspicuous floral component of the station depending upon which of the segments is under consideration, i.e., the bottom algae in the ponded reach and the floating algae in the riffled stretch of water. As a result, one or the other of these two algal groups, the Characeae, and the remaining macrophytic taxa not mentioned above (Carex, Eleocharis, Myriophyllum spicatum, and P. pectinatus) denote the dominant and subdominant plants of one or both of the station V locations.

Major Taxa and Abundance Evaluations. The spike-rushes can be rated as a subdominant taxon in both the riffle and ponded sections of station V, and the floating algae group can be classified as a subdominant component of the station V pools. However, the floating algae were largely nonabundant in the riffle reach.

The four dominant taxa at station VR, listed in the order of their descending total station WCC percentages, were tabulated as follows: Carex, M. spicatum, the bottom algae, and P. pectinatus. These four taxa generally represented the most abundant, ubiquitous, and conspicuous plants at this lower East Poplar riffle site with the highest CC, TF, and Abio values, but the term dominant in this cast typically refers a lower WCC percentage for the station VR dominants than the WCC's that were recorded for many of the dominant plants in the ponded segments of the upstream locations. Of these dominants, the WCC's of the lower ranked taxa at station VR were the most similar to the WCC's of the correspondingly ranked plants at the other sites. The various taxa in the subdominant class also demonstrated generally similar abundance levels among the Poplar stations, although Eleocharis did afford a relatively low canopy cover reading in the station VR reach.

To a less marked degree, the same dominance-abundance relationships noted above were observed in the station VP reach, and the four dominants in this segment, M. spicatum, P. pectinatus, Carex, and Characeae ranked according to WCC, often showed lower WCC levels than the dominant plants that were tabulated at the upstream sites. Such inter-segment abundance differences were again most obvious with respect to the more highly ranked members of this dominant plant coterie.

The comparatively low canopy covers of the dominant plants at station V generally coincided with the lower total CC's that were typically calculated for the riffles versus the pools, and they also coincided with the lower total CC's that were obtained for the station VP segment versus the ponded reaches of the midway and upper parts of the East Poplar River. Such a reduced total macrophytic abundance at station V relative to the upstream sites describes one of the principal vegetational differences that was recognized between the lower East Poplar and the middle and upper portions river. This downstream drop in canopy cover was undoubtedly related to the less amenable physical conditions of the two station V components where its pools demonstrated coarser bottom materials than the upstream locales and with its riffles providing coarser substrates, more rapid current velocities, and much shallower waters than the ponded segments. As a related observation, the total plant abundances of station VP were most similar to those at the extreme upstream station I reach at the international border which also afforded less than ideal conditions for submersant macrophyte growth because of its channel-like physical features and because of a high level of biotic competition from its dominant emergent forms.

Intra-Station Segment Comparisons: Dominant Taxa. Comparisons of the dominant taxa rankings of the riffle and ponded reaches at station V, as listed previously, additionally point to the general floral similarity of the two station V segments with these waters containing the same dominant plants except for a bottom algae enhancement in the riffle section in place of the charophytic algae that were abundant in the ponded reach. However, two other inter-segment floral differences were also identified at station V in addition to this algal interchange and the reduced diversities that were noted for the riffle versus the ponded locations, and these further comparative aspects are summarized below.

First the rankings of the dominant taxa and the ranking order of the plants differed to some extent between the two station V segments. That is, the emergents tended to be more prevalent than any single underwater taxa in the shallow riffle section, while the submersants tended to be more common than any single out-of-water plant in the deeper ponded reach.

In the second comparison, fairly obvious inter-reach canopy cover differences became evident in the station V inventory data with reference to the following two items: CC differences between an abundance ranking of one segment and the same ranking of other segment without regard to any particular taxon, and differences between the CC values of a dominant taxon in one segment and this same plant in the other reach without regard to its abundance rankings. In most of these cases, the CC levels of the plants were found to be lower in the riffles of station V than in the ponded portions of the site in accord with the harsher physical features of the riffle section. But in spite of such CC discrepancies, the floral similarities of the two station V segments were still quite distinct, especially in view of their pronounced depth, velocity and substrate differences, and the pool to riffle physical changes that were described earlier primarily acted to reduce the plant abundance and diversity levels of the latter reach while not altering the basic floral compositions of the two contiguous stream segments to any overriding degree.

Upstream Comparisons. Of the eight miscellaneous taxa identified at station V, Sagittaria and Scirpus were found to be dominant in some of the upstream reaches, although they became non-prevalent downstream in the lower East Poplar in association with the coarser substrates of the lower river. Excluding P. foliosus, the other five minor true macrophytes of Table 20 were also present at several of the upstream locales but at relatively low abundance levels as noted for the station V waters, while the somewhat rare P. foliosus demonstrated a much more restricted type of distribution. Of course, a number of the major and minor taxa in the upstream waters were not collected from the lower East Poplar (e.g., P. richardsonii, P. robbinsii, Sparganium, and Typha).

With reference to the major taxa of station V, the five dominant and subdominant true macrophytes of this site were also quite prevalent in many of the upstream waters. Furthermore, the relatively high algal CC's of station V, assuming either a floating or a bottom habit depending upon the segment, were in accord with the general downstream increases in the abundance levels of these plants that were observed for the East Poplar River. To a large extent, station V presented a floral amalgamation of particular components of the taxa characteristics of the border and the midway stations, and as a result, the lower East Poplar reach was not as floristically distinct as the various upstream sections. The floral distinctiveness of station V, therefore, became most evident in a negative sense through the absences or lower relative abundances and closer CC equivalencies of the aquatic macrophytes that happened to be notably dominant at certain of the upstream sites, and station V did not demonstrate a uniquely high abundance value for any single plant form as was noted for each of the other East Poplar locales, i.e., Sagittaria, Typha, Characeae, and M. spicatum in a downstream order from station I to station IV. Thus, a taxon from station V cannot be readily fit into this downstream sequence listing of novel taxa that had comparatively high CC percentages on a site-dependent basis.

The dominance of M. spicatum at station V was carried downstream from the high abundances of this species at the midway and the near border sites, and P. pectinatus at station V tended to regain its dominant stature of the station II and III segments after being an inconspicuous component of the middle East Poplar pools. Since P. pectinatus, in contrast to the milfoils, appeared to have some type of current requirement, this mid-river to lower river enhancement of pondweed CC percentages was possibly reflective of the occurrence of a low level current velocity in the station VP waters in contrast to the non-currented nature of station IV which was totally dominated by M. spicatum. As a result, the intermediate sector (slow current) versus middle sector (faster current) cross-stream distributional pattern of M. spicatum and P. pectinatus that was described earlier also became evident to some extent in the lower East Poplar, VP reach (Table 20), although these relationships were much less obvious in this lower segment than they were for the two species at stations II and III.

As a further feature along these lines, the abundance of the Characeae at station VP was probably related to the extreme maximum depths of this site in relation to the charophyte's optimum deep water needs. However, these macrophytic algal were much more abundant at station III than at station V in response to the lower overall depth readings of the latter segment (Table 11).

Algal Relationships. Possibly the most distinctive floristic feature of the community at station V revolved around the dominance of the bottom algae in the riffle section of the site in contrast to the low abundances of this algal group in the ponded segments of the Poplar stations. Such CC variations are suggestive of a riffle requirement by this plant assemblage, and this requirement can be illustrated by the group's low optimum depth value and by its high optimum current velocity and high optimum substrate reference numbers as follows: depth = 0.41 feet, current speed = 0.20 fps, and substrate index = 3.95 units. The riffle-like optimum physical needs of the bottom algae were markedly different from the pool-like physical dimensions that were required by the charophytes, the submersant macrophytes, and the floating algae in order to achieve their maximum CC levels, and these optimum discrepancies were thereby reflected in the differing distribution-abundance patterns of the bottom algae relative to the patterns that were outlined by the pool-loving plants of the study region.

The floating algae were also fairly abundant at station V in the ponded portion of the reach, and dissimilar from the bottom group, the floating forms required the absence of a distinct stream current and a near zero surface velocity in order to become established at any given lotic location. Also, the occurrence and abundance of the floating algal group appeared to be largely independent of water depth and substrate composition with the physical optimums in these cases, 0.85 feet and 2.16 units, fairly close to the depth and index averages for all of the appraisal sites. These features in turn, might be expected for any plant group such as the duckweeds or the floating algae that might have a neustonic type of growth habit.

As a further consideration with respect to the two algal groups, the greater CC's of the bottom and floating algae in the riffle or ponded sections of station V in relation to their lower CC levels at the macrophyte-dominated upstream sites coincides with the comparatively low total abundances of the higher plants in the station V segments. This relationship indicates that a reduced biotic competition from the true macrophytes, as would be the case for the lower East Poplar, might be another essential factor for the development of a relatively pronounced algal abundance along with the availability of the necessary physical characteristics which appear to be present at the station V riffle and pool locations. Thus, an operation of both the physical and biotic factors of the streams probably played an interrelated role in relegating the magnitude of algal CC levels through the Poplar study region, and this same interplay can be invoked for all of the Poplar plants as intimated earlier. Station V, thereby, apparently provided the best mixture of these affecting factors for algal ecesis of any of the appraisal sites as attested by the station's comparatively high algal abundance levels.

Community Characteristics of the Ponded Segment

Abundance Rankings and Variations and Upstream Comparisons. The station VP reach on the East Poplar demonstrated a significantly lower total macrophytic canopy cover value than the three most immediate upstream sites, and this was due to the comparatively low CC's of both the emergent and the submersant associations along the station VP segment. The VP emergents and submersants each afforded a fourth ranking in WCC among the inventory stations, and this combination led to a fourth ranking with reference to the total emergent plus submersant (E + S) WCC percentage of the lower East Poplar. As a result of this feature, the East Poplar revealed a general downstream decline in total CC through the ponded reaches in conjunction with a gradual lowering of the physical suitability of the more downstream locations for the establishment and development of macrophytic vegetation, and this decline was carried into the upper Poplar mainstem.

The general downstream pattern of decrease in the total E + S WCC percentages of the stations can be summarized as follows: 75.4 at II, 62.2 at III, 71.6 at IV, 46.7 at VP, and 7.5 in the upper mainstem (VIP). However, the relatively low total WCC of station I (43.1%) provided a major deviation to this downstream pattern, and this station I discrepancy was probably caused by the less amenable physical nature of the channel-like border reach. Otherwise, the downstream drop in total WCC was fairly consistent as shown, and it was much more pronounced from the middle to the lower East Poplar and into the upper mainstem than it was from station II to the middle reach because of the less distinct physical changes that developed through the latter comparison.

But the downstream decline in plant abundance along the East Poplar was observed to be somewhat less consistent when the WCC's of only the submersant forms were reviewed because of the elimination by this manipulation of an inter-association abundance compensation from the emergents at each of the sites. Furthermore, this decline was least consistent with a high degree of variability in relation to the emergent plants as a result of the substrate composition variations that were present along the river in the E to NE sectors of the stream. The longitudinal effects of these interstation stream bottom alterations on emergent growth will be considered later.

As indicated in Table 20, the weighted and true canopy covers (WCC and TCC) of the station VP emergents demonstrated a sharp cross-stream decline in magnitude from the bank to the middle of the river in conjunction with the increasing depth values of the E to the M sectors, and the deep central portions of the reach were thereby totally denude of any out-of-water vegetation. At the same time, the submersant WCC and TCC levels increased by sixteen-times across the lower East Poplar segment from the E to the IM sectors in response to these increasing water depths, although a near 35% drop in submersant abundance then occurred into the center of the stream in accord with the similar midstream declines that were noted for many of the other stations.

Because of the occurrence of the inter-association abundance compensations that were outlined earlier, the total E + S WCC levels of station VP were observed to be fairly constant through its E, NE, IE, and IM sectors in the face of the emergent-submersant variations. But a marked drop in total WCC did occur into the middle locations in accompaniment with the midstream decline in the CC's of the underwater plants in association with the absence of any emergent vegetation. The E + S WCC's also showed a very slight decrease at station VP from the NE to the IM locations, but this decline was much more distinctive with reference to the total TCC variable than it was on a WCC basis with the TCC expression showing a greater amount of variability all across the stream. Relationships between the weighted and true canopy cover parameters of the inventory are discussed below. For the most part, the inter-sector WCC alterations at station VP were typical of those that were observed throughout most of the study region, but specific and partial modifications to this basic format did become evident at some of the appraisal sites.

Weighted-True Canopy Cover Comparisons. Like the WCC expression, a downstream decline in plant abundance along the East Poplar again became evident with reference to the true canopy cover expression, and station VP also afforded a fourth station abundance ranking on the basis of this second parameter. This correspondence between WCC and TCC along the East Poplar stems from the marked positive correlation that was obtained between the two canopy cover variables, and their rank and parametric correlation coefficients were found to be statistically significant at much less than 1% for the nine possible WCC-TCC station comparisons ($r_s = 1.00$ and $r = 0.98$). Because of such a close correlation, any comparative interpretations that might be derived from the WCC data, which formed the focus of discussion for this report, can be similarly drawn from the TCC numbers in a large majority of the cases. Sector comparisons between total WCC and total TCC at each of the stations also typically produced high cross-stream rank correlation coefficients with an overall r_s value in this instance equal to 0.69 at the 1% level of statistical significance.

The comparative discrepancies that did happen to arise between WCC and TCC were related to the occurrence of plant biomass differences across the same comparisons because of the incorporation of a biomass factor into the WCC expression. In some of the cases, WCC tended to change to a greater extent than TCC, and this discrepancy appeared when a drop in plant abundance, as described by a difference in the density-based CC percentages, also involved a corresponding decline in the overall biomass levels of the comparatives as illustrated by their ABio values.

One example of such WCC-TCC-ABio relationships is found in the station V pool to riffle comparison where total station WCC declined by 56% and total TCC dropped by only 30% in conjunction with a 39% decline in the segments' ABio levels along this same R to P direction. However, the percentage difference of TCC from comparative to comparative and the percentage difference of WCC from comparative to comparative were more closely similar than the above example in those cases where the ABio values did not differ to such a marked degree. The emergent-submersant comparison at station IV falls into this category with 18%, 17%, and 2% differences between associations in WCC, TCC, and ABio respectively. As a further variation on this theme, in comparisons where the ABio's actually showed an increase in opposition to a drop in TCC, then the WCC's afforded a less pronounced decline than TCC, or even an opposing increase in the more extreme cases, and the magnitude of the inter-variable discrepancies in these situations was dependent upon the degree of the ABio change.

The total WCC and total TCC inter-sector comparisons of station VP provide examples of the latter relationships mentioned above because of the station's E through M sector increases in ABio and its corresponding E through M declines in TCC; TCC, therefore, varied to a greater extent across the stream than WCC. But regardless, any of the WCC-TCC variations of this kind that did become evident in the study data were generally quite minor, and they did not alter to any significant extent the major plant abundance interpretations that could be derived from the results of the inventory. On an absolute basis, the TCC values consistently exceeded those of the WCC expression because of the way that the two parameters were mathematically defined at the outset of the data evaluations.

Diversity and Biomass Aspects. The identification of fifteen plant groups in the lower East Poplar coincided with a general downstream drop in total station floral diversity along the river with a greater number of taxa collected from the upstream segments than from the lower reach, and this decline in diversity was culminated in the upper Poplar mainstem. However, the total transect point diversity of station VP can still be rated as relatively high with a higher overall Taxa/Pt. reading than most of the upstream locations. This feature indicates that the smaller assortment of aquatic taxa in the lower river was distributed across the stream in such a fashion so as to preclude an occurrence of the distinct homogeneous vegetative stands that were observed for the milfoils at station IV and the arrowheads at station I. Thus, although the Taxa/Pt. values tended to drop in a midstream direction at station VP, as was observed for most of the sites, they remained comparatively high in the NM and M sectors of station VP because of a heterogeneous intermixing of the lower East Poplar's three dominant submersant taxa through the central portions of this downstream segment.

The highest Taxa/Pt. value of station VP was obtained from the ecotonal NE sector of the stream where plants from both the emergent and submersant associations tended to converge to a significant extent. Almost all of the station taxa were identified in this ecotonal section of the reach. A slightly lower point diversity was obtained from the emergent-dominated E sector of the station with the recognition of ten taxa, and a decline in this variable then occurred into the submersant-dominated middle parts of the stream with the collection of only five underwater forms. In an opposite fashion, the ABio levels of station VP demonstrated a distinct and consistent transverse increase from the E to the M sector of the reach as has been noted for the upstream sites.

Also unlike the Taxa/Pt. expression, the total station VP ABio, by having only a moderately high ranking, was found to be lower in magnitude than the high and extremely high ABio's that were recorded for the middle and upper stations on the East Poplar River. This somewhat low ABio at station VP, thereby, was in concert with the station's comparatively low total WCC percentage.

As a general observation, the size of the overall Taxa/Pt. values at the different appraisal sites was not totally dependent upon the total numbers of taxa tabulated, but was also dependent to a significant degree upon the basic structure of the macrophyte communities in terms of the distributional pattern of the plants across a stream reach. This aspect of the study area is exemplified by comparisons among the station I, IV, VP segments where the higher or equal total taxa numbers of the first two stations with their homogeneous tendencies provided lower Taxa/PT. readings than the VP reach with its more heterogenous type of plant organization. Therefore, the Taxa/Pt. expression did not demonstrate any consistent trend of downstream change along the East Poplar as was observed for the total number of station taxa identified; rather, the Taxa/Pt. values were quite variable and were dependent upon the homogeneous-heterogeneous structural features of the different plant communities.

Because of this Taxa/Pt. variability along the East Poplar, the adverse downstream physical changes that developed from the upper-middle to the lower sections on the river did not appear to influence the distributional or point diversity characteristics of the stream's plant communities. But these physical alterations did act to reduce the number of taxa collected, and these physical changes also acted to reduce the total plant abundance levels of the lower East Poplar. Such abundance reductions became obvious in the inventory data both on a canopy cover-density basis (TCC) and on the basis of the communities' biomass levels or ABio. Furthermore, the physical degradations that were observed to occur in the Poplar system did eventually achieve an adequate degree of severity so as to retard point diversities within the upper drainage mainstem, the Middle Fork, and the station VR segment in association with the much lower CC's, ABio's, and floral diversities of these particular inventory sites.

Inter-Association Biomass and Canopy Cover Comparisons. In conjunction with the relatively low total ABio levels of station VP with reference to the upstream sites, this lower East Poplar reach also provided a somewhat high total TCC/WCC ratio (3.07), although this ratio was not excessively high in relation to the 2.2 to 2.7 TCC/WCC values that were calculated for border and middle river locales. The emergent and submersant associations at station VP, in turn, afforded closely similar total ABio's (near 3.2) and total TCC/WCC ratios (3.21 versus 3.02) with the second plant category providing only a slightly higher biomass level than the other classification. This close biomass equivalence between the two groups became evident in the data even though the underwater taxa demonstrated a much greater overall WCC percentage than the emergent forms.

These parametric comparisons indicate that the inter-association abundance difference at station VP was due primarily to a true CC or density discrepancy between the plant assemblages, as highlighted by the absence of emergent vegetation from the middle river sectors, and it was not related in any significant degree to the minor biomass discrepancy that was uncovered between the separate vegetative forms. Thus the out-of-water plants provided fewer station counts than the submersants, resulting in the emrgent's lower CC percentages, while the individual counts in both of the cases provided almost equal biomass ratings with this feature resulting in the nearly equal ABio values of the two plant classes. Because of this ABio similarity, the WCC and TCC percentage differences between the two associations at station VP were nearly equivalent at 67% and 65% respectively.

In contrast to station VP, the lower CC's of the emergent association at station II with the emergents' reduced total tabulations actually demonstrated a higher ABio value than the more dense submersant group. This site, therefore, provides an extreme example of the emergent versus submersant, density (TCC) versus biomass (ABio) plant abundance discrepancies that can be seen at some of the locations in the study region streams. However, the two abundance expressions were in much closer accord at some of the other stations, e.g., stations I and III, where the lower CC's of one of the associations (i.e., the submersants at I and the emergents at III) also revealed the lower biomass level. In the case of station IV, the fairly similar CC's of the two plant groups also afforded fairly similar ABio readings. In the main, the type of inter-association abundance relationship that was observed at a site was dependent upon the structural characteristics of the plant community that was found to occupy that particular reach, and a number of theoretical combinations are feasible in this regard involving a density and/or a biomass dominance and/or equivalence of one or both of the associations with reference to the other group.

General Physiognomy. In light of the moderately high TCC/WCC ratio that was calculated for the station V pools, and in view of the segment's relatively high Veg. CC percentages and its low bare substrate frequencies and low ABio readings within the E and NE sectors of the site, the near shore plant association at station VP presented a mode of community physiognomy that can be best described as imparting a carpet-like texture to the stream bottom materials that were present in the shallower sections of this ponded reach. This near shore plant grouping at station VP was dominated by the diminutive sedge and spike-rush emergent forms with the scattered occurrence of a small assortment of submersant taxa and other emergents that were tabulated in comparatively low abundance levels.

But as a result of the marked transverse increase in bare substrates and the decline in Veg. CC to the middle portions of the station VP reach, the more midstream plant associations of this site, with their higher ABio values and with the general absence of any emergent vegetation, presented a broken and submersant mound-type of physiognomy instead of the continuous carpet style of organization that was characteristic of the shallow water plants. The underwater mounds at station VP also stood in sharp contrast to the emergent arrowhead mounds that were examined in the station I segment, and the clumps of plant growth that prescribed the mounds of the lower East Poplar were less distinct vegetatively than these arrowhead aggregations and the pronounced underwater weedbeds that were encountered in most of the upstream segments. This vegetative aspect is illustrated by the higher TCC/WCC and the lower ABio values of the VP submersants. The mounts at station VP were typically comprised of either Myriophyllum spicatum, Potamogeton pectinatus, or Characeae depending upon the stream location, but they did have a liberal sprinkling of one or both of the other dominants at about 50% of the secondary lines with the other half of the transect points being homogeneous in nature.

Community Characteristics of the Riffle Segment

Intra-Station Segment Comparisons: Abundance Rankings and Variations. Several distinct plant abundance and diversity differences became evident between the plant community in the ponded reach of station V and the community in the riffle segment of the site in association with the less suitable physical environment that was found in the latter East Poplar section for the establishment and growth of macrophytic vegetation. The various abundance discrepancies that were spotted between the two station V locations can be summarized as follows:

Most obviously, the riffles demonstrated lower macrophyte abundance levels as density than the station V pools. This difference was quite evident on an overall station basis for both the WCC and TCC parameters through both the emergent and submersant associations, and it was also evident in relation to the station's total E + S CC expressions. In addition, these same differences were observed for each of the station's sectors with the riffles showing lower canopy cover values than the pools in all of these more specific comparisons. As a result of these features, the station VR reach received a lower fifth-place abundance ranking among the sampling sites than the ponded section for both the emergent and submersant plants, and station VR received sixth-place ranking in terms of its total E + S percentage.

In parallel with riffle's relatively low canopy cover values, this stream segment also provided lower Veg. CC percentages and higher bare substrate frequencies than the pools through most of the transverse sectors. These Veg. CC differences between segments can be seen as particularly pronounced when the algae are eliminated from the abundance comparisons by considering only the true macrophytes, and such non-algal features can be illustrated by reviewing the Bare-Alg. parameter. With reference to this Bare-Alg. variable, nearly 50% of the riffle's transect points revealed only algal growth or bare stream bottom materials so that the algae provided about one-third of the riffle's submersant WCC value and about one-fourth of the riffle's Veg. CC reading. The algae made lower one-sixth and 1.5% contributions in the ponded reach of station V, and these same plants made even lower contributions at the several upstream sites (e.g., 3% and 0.3% at station II).

Similar to the ponded reach, the emergent CC's of the riffle sectors demonstrated a marked transverse drop toward the center of the stream (Table 19), but the submersant and total CC's of the sectors were much more variable across the segment in the riffles than in the pools with a less consistent pattern of change in the riffle case. The IM to M sector decrease that was observed for SCC and total CC in the pools was also evident in the riffles in response to the coarser substrates and higher current velocities that were encountered in the central parts of the lower East Poplar. However, the riffles tended to show an overall bank to midstream decline in SCC and in total CC in contrast to the pronounced E to IM increase in submersant abundance that was observed for the pools and in contrast to the general E to IM constancy in total CC that was noted for the station VP segment. These latter discrepancies were probably due to an absence from the riffles of the marked cross-stream depth increases that occurred in the ponded section which would act to enhance the viability of the underwater forms. As a result, the total WCC of the submersant plants exceeded that of the emergents to a greater extent in the pools (3.1-times) over the riffles (2.0-times), while the emergent ABio value of the shallow riffle reach was greater than the ABio of its underwater plants with the reverse observed to be true for the deeper ponded segment of station V.

These riffle versus pool abundance differences also became evident in the biomass data of the inventory as reflected in the ABio numbers of the VR and VP segments. Like the CC values, the pool's overall station ABio's were higher than those of the riffles for both the emergent and the submersant associations, and they were higher on a total station E + S basis. In addition, these E + S ABio's were greater in the pools than riffles for all of the station sectors. Since the riffle ABio's did not demonstrate the edge to middle transverse increase in magnitude that was seen for the ponded reach, the biomass discrepancies between the two segments became most pronounced and quite distinctive in the more midstream sectors where the inter-reach physical differences in depth and current velocity were found to be the most obvious.

As an accessory note, the transverse variations in SCC, total CC, and ABio across the riffle segment appeared to be generally and negatively related to the cross-stream ups and downs of this segment's substrate reference number. Along with these transverse physical changes, the longitudinal physical deteriorations that occurred from the ponded to the riffle sections of station V, which involved a marked increase in the substrate index number, also significantly affected the plant abundance characteristics of the stream's macrophyte communities as just described, and such effects were observed to extend into the diversity aspects of these morphometrically separated plant assemblages.

Intra-Station Segment Comparisons: Diversity and Physiognomy. As noted previously, the riffle portion of station V exhibited a low floral diversity with the collection of a fewer number of plant taxa from the VR segment than from the moderately diverse station VP reach. This diversity discrepancy between the two stream sections also became evident on a transect point basis with the riffles affording a low station Taxa/Pt. reading in relation to the high value of this variable that was calculated for the ponded stretch of water. Like the station V pools, the Taxa/Pt.'s of the riffles declined cross-stream from the somewhat diverse, ecotonal NE and IE sectors to the middle of the river, but since the Taxa/Pt.'s were much lower in the riffles than in the ponded station V locations through all of the sectors, the midstream riffle sectors provided for relatively homogeneous plant aggregations with reference to the more floristically heterogeneous secondary lines that were examined in the NM and M sectors of station VP. That is, only about 20% of the transect points having vegetation in the middle river parts of station VR demonstrated more than one taxa in contrast to a 50% rating for the more midstream sectors of the ponded reach at this same appraisal site.

In conjunction with the low Taxa/Pt. diversity of the station V riffle and its moderate ABio ranking, the VR site also produced a relatively high station TCC/WCC ratio (4.81), and similarly high ratios were obtained from both the riffle's emergent (4.00) and submersant (5.22) associations. These high TCC/WCC values plus the low Veg. CC percentages of the VR segment and its high Bare Sub. and Bare-Alg. frequencies point to the occurrence of a much less distinctive kind of plant community in the station V riffle relative to what was observed for the lower East Poplar pools and the river's upstream reaches.

In the case of the Carex- and Eleocharis-dominated emergent plant grouping at station VR that was located near the banks of the stream (in the E and NE sectors), the near shore physiognomy of these plants appeared to occupy an intermediate position between a community that has a carpet-like aspect and one that has a mound-like format. But this VR "carpet" had a comparatively sparse and "tattered" appearance because of the high bare substrate frequencies of the near shore locations, and the VR "mounds" were not particularly pronounced vegetatively because of their low ABio ratings.

A similar form of hybrid and nondistinctive community physiognomy was also presented by the plants in the deeper intermediate stream sectors of station VR, and the only major difference between this grouping and the near shore association revolved around the fact that the macrophytic components of the offshore locations were largely submersant in nature with a generally different set of taxa and with only a few of the out-of-water tabulations. The Bare Sub. and Bare-Alg. percentages were probably not adequately high at either the E-NE or the intermediate stream positions to be indicative of the truly scattered style of community physiognomy that was described previously in this report. This scattered community motif represents one of four basic categories of plant organization that were defined for the inventory with reference to the manner of vegetative parameters that were available from the project data, and it can be characterized by its extremely low biomass levels and its extremely low density features.

In contrast to the E through IE sectors of the station VR segment however, the Bare Sub. and Bare-Alg. percentages of this particular reach were distinctively high in its two midstream sectors, and the underwater vegetation through the central portion of the station V riffle with the plants' low ABio's (values near 1.9) can be described as having a scattered and extremely sparse mode of organization. This appearance was especially notable in relation to the true macrophytes. In essence, the midstream plant association at the VR site was comprised of fairly widespread and typically diminutive single sprigs of either Myriophyllum spicatum, Potamogeton pectinatus, or P. foliosus with occasional growths of the bottom algae interspersed at scattered spots among these higher plants. Totally bare substrates were tabulated at about 40% of the middle river secondary lines at station VR, while the bottom algae covered about 27% of the remaining mid-river stream bottom. The true macrophytes, in turn, covered only approximately 33% of this mid-river streambed. For comparison, the bare substrate, algae only, and the true macrophyte percentages plus ABio's that were tabulated for a selection of stream locations that had the contrary and non-scattered types of vegetative physiognomies can be listed in order as follows: 22%, 7%, and 72% with a 2.50 ABio for the "tattered" near shore "carpet" at station VR; 8%, 0%, and 92% with a 5.25 ABio for the dense and midstream submersant weedbeds at station III; 0%, 0%, and 100% with a 3.68 ABio for the dense and near shore emergent stands at station IV; 36%, 10%, 53% with a 4.13 ABio for the emergent midstream mounds at station I; and 40%, 1%, and 59% with a 3.94 ABio for the submersant midstream mounds at station VP.

Among the dominant NM and M sector plants of the central riffle association at station VR, P. foliosus, like the bottom algae, was somewhat unique for the study region in showing its highest canopy cover levels within this physically harsh, midstream riffle environment with the segment's low plant abundance levels. But in the main, these middle riffle sectors and the riffle segment in general provided conditions that were largely borderline for the establishment, development, and growth of true macrophytic underwater taxa and vegetation, and these negative aspects were even more pronounced in the upper Poplar mainstem.

Substrate and Emergent Abundance Relationships. The WCC percentages of the emergent plants in the E and NE sectors of station V, and the station's total E + S WCC's in these locations, demonstrated a near 45% decline from the pool to the riffle sections of the appraisal site. This drop in plant abundance coincided with an approximate two-fold increase in the substrate coarseness of the E and NE sectors in this same P to R direction as illustrated by the marked differences between the appropriate substrate index numbers (Table 11). This correlation suggests that the stream bottom materials of the Poplar drainage played an important role in relegating the abundance levels of the emergent macrophytes along the basin's rivers, and a similar relationship between ECC and substrate was observed with respect to the middle and the three border stations on the East Poplar in association with the river's lower reach. In these comparisons, stations II and V revealed low ECC percentages in response to their comparatively high E-NE substrate indexes (greater than 1.2 units), while stations I, II, and IV provided much higher ECC's in accord with the finer-grained nature of their bottom materials (index values less than 1.15 units). Furthermore, the upper Poplar mainstem station and the site on the Middle Fork also afforded low ECC percentages in concert with their high near shore substrate reference numbers (between 2.0 and 4.2 units).

This inverse relationship between emergent abundance and substrate composition was confirmed statistically by calculating rank correlation coefficients between the emergent WCC's and the substrate indexes of the E and NE sectors of the nine sampling sites. The out-of-water vegetation of the study region tended to be most prevalent in these near shore sections of the streams, and a pronounced and negative r_s value of -0.81 that was statistically significant at less than 1% was obtained from this analysis for the eighteen possible combinations. A negatively significant (at 1%) but slightly lower r_s of -0.72 was obtained from the IE and IM sectors where the emergents were observed to show more moderate abundance levels. However, the negative r_s between ECC and substrate coarseness for the NM and M sectors of the stations (-0.40) was found to be much lower than those from the other sector evaluations, although this midstream r_s was still significant statistically at the 5% level. The lower nature of this mid-river correlation was probably a reflection of the low emergent CC percentages that were tabulated for the deeper central portions of the streams, and other affecting factors such as depth and submersant competition were probably more important in regulating the development of emergent vegetation than substrate in these midstream locations.

The results from the above analysis indicate that the bank to midstream changes in substrate coarseness that occurred at most of the stations, as described by the transverse increases in the substrate reference numbers of the E to M sectors, were probably at least partially instrumental in causing the reductions in emergent abundance levels that were observed towards the center of the streams. Such adverse effects from substrate would then work in concert with the negative effects on emergent vegetation that were derived from the cross-stream depth enhancements. A relatively pronounced and inverse overall rank correlation coefficient was obtained in a shore to middle location direction between the emergent WCC percentages and the substrate indexes of all of the station sectors, and this overall transverse r_s value (-0.74) was statistically significant at less than 1%. As a result, the stream sectors having the higher ranked substrate reference numbers tended to have the lower ranked emergent abundance levels, and vice versa, and this relationship was generally evident from both a transverse perspective when looking across the streams and from a longitudinal perspective when looking up and down the lotic waters of the study region.

The longitudinal change in emergent abundance that was negatively correlated with an increasing coarseness of the streams' near shore bottom materials involved a basic alteration in the floral compositions of the Poplar's out-of-water plant associations. The basin's dense and luxurious stands of Typha were dominant in the presence of an extremely fine-grained substrate, while Scirpus was the most prevalent of the emergent taxa on the more moderately fined-grained materials. These two genera were much less abundant on the coarser substrates, and the bulrush WCC percentages, thereby, afforded a negative and significant rank correlation coefficient with the substrate indexes of the stations' E and NE sectors ($r_s = -.49$). Although Carex and Eleocharis were also present on the fine-grained substrates, they were nondominant in these situations, and the generally diminutive and comparatively sparse sedge and spike-rush growths became prevalent in the face of the higher substrate reference numbers.

If the sedges and spike-rushes can be viewed as the pioneer plants of a coarse-grained to fine-grained vegetational transition, then the general succession that occurred from the low density-low biomass and Carex-dominated seral stage on the coarse-grained streambed materials to the high density-high biomass and Typha- or Scirpus-dominated climax and subclimax on the finer-grained materials essentially produced the higher emergent abundance values that were found in conjunction with the lower substrate index numbers. Such floral shifts in accompaniment with the substrate alterations closely coincided with the differing substrate optimums of these emergent taxa, and the end result of these changes in taxa and substrate compositions was a variation in the total emergent abundance levels of the Poplar streams.

Depth and Emergent Abundance Relationships. The adverse effects on emergent growth of the shore to midstream depth enhancements of the Poplar streams were seen to be quite obvious in light of an average E to M, six-fold increase in this physical variable for the ponded river segments. This negative relationship was confirmed by the fact that the overall transverse rank correlation coefficient between emergent WCC and sector depth was statistically significant at less than 1% for a combined analysis of all of the stations ($r_s = -0.86$). However, nonparametric and longitudinal correlations between emergent WCC and depth could not be shown to be significant for any of the three E-NE, IE-IM, and NM-M sector combinations with relatively low values calculated for each of these cases as follows: 0.05, -0.07, and -0.22 respectively.

The results from the longitudinal correlations suggest that the upstream-downstream depth variations along the three longitudinal sector bands of the streams, which provided for only a typical 1.5-fold depth difference in the non-riffle waters, were of an inadequate magnitude in the face of other affecting factors such as substrate to additionally influence the abundance characteristics of the emergent vegetation that did become established within each of these separate locations. That is, the primary transverse increase in depth towards the center of the streams greatly curtailed the amount of emergent growth that could undergo ecesis in the deeper sectors, but the smaller secondary and longitudinal changes in depth from station to station through these deeper waters did not act to further alter to any significant degree the already low abundance levels of the out-of-water plants.

In a similar fashion, the slight inter-station depth variations that occurred in the shallow near shore waters where the emergents provided their highest canopy cover percentages also did not function to change out-of-water abundances to any marked extent. Moreover, this particular non-effect of depth was observed to apply to the somewhat deeper waters of the E-NE sectors at station VII where these waters were associated with the Middle Fork's fairly pronounced streambanks. The coarse substrates of station VII, therefore, were seen to be a more important influential variable than depth in controlling emergent CC along the shores of the Middle Fork reach, and this was also the case for the other study segments.

Effects of Current on Emergent Abundance. The comparatively low current velocities of the study area streams with reference to those that are typically measured in many lotic systems did not appear to be of a sufficient intensity to markedly affect the abundance levels of emergent vegetation within the Poplar drainage. Furthermore, the pronounced effects that were observed to arise from depth and substrate would tend to mask any influences that might be directly related to the velocity variable. These features were illustrated by the fact that the longitudinal and overall rank correlation coefficients between emergent WCC and current speed for the E-NE, IE-IM, and NM-M sector bands of the stations were relatively small and insignificant statistically at 5% with r_s values of -0.22, -0.30, and 0.16 respectively; these low correlations were obtained even though the velocities within some of the bands varied to a fairly pronounced degree (Table 12). This suggests that the E to M increases in velocity that occurred at most of the stations, which were oftentimes less distinct in magnitude than the longitudinal changes, were also inadequate to retard emergent WCC values in a transverse direction to any notable level.

Such assumed non- to minor influences of current speed across the rivers cannot be confirmed statistically by using a simple rank correlation analysis because any effects stemming from the midstream velocity enhancements would run in parallel to the cross-stream negative effects on the emergents that were derived from the depth and substrate variables. In addition, the pronounced negative correlations that were obtained from both the ECC and depth and the ECC and substrate comparisons were probably due to a synergistic interaction between these two physical parameters with the two variables working in concert to reduce emergent canopy cover. However, applications of the involved multiple correlation and regression parametric evaluations that would be needed to specifically separate the influences of velocity, depth, and substrate on the Poplar's aquatic plants were beyond the scope of this report. Nevertheless, the low velocities that were measured in the Poplar streams indicate that the effects of this variable on the basin's out-of-water vegetation might be judged as minimal with a fair degree of confidence as illustrated by the preliminary rank correlation analyses described above.

The negative natures of the E-NE and IE-IM r_s coefficients suggest that current may have had a small adverse impact on the emergent plants that was seen as a slight lowering of the association's CC percentages. A more complex statistical assessment along these lines to more definitely quantify such physical factor-plant abundance relationships could form the focus of future analytical work on the results of the inventory, and the physical and vegetative data that would be necessary for these refined evaluations are available in the tabular presentations of this present write-up.

Depth and Submersant Abundance Relationships. In contrast to the emergent vegetation, the submersant plants of the Poplar drainage demonstrated a favorable response to increasing water depths, and extremely high positive rank correlation coefficients between sector depth and SCC were calculated for some of the appraisal sites. For example, r_s values of 0.89 and 0.94 were obtained at stations II and III for this type of comparison. But the overall transverse rank correlation between depth and underwater WCC across the E to M sectors of all of the stations, though statistically significant at about 5%, did not afford a distinctively high coefficient with an r_s reading of only 0.36. This relatively low total depth correlation indicates that other factors in the study region were also probably influential in regulating submersant growth at particular stream locations, and the impact of these extra-depth variables on the assessments were sequentially reduced in the statistical analyses by correlating on a progressively smaller set of stations where the non-depth factors appeared to be less important. The results of these sequential analyses are summarized below.

The transverse submersant WCC-depth correlation was first improved by eliminating the two shallow riffle segments from the data base (stations VR and VIR) with their small depth alterations and their coarse substrate features, and a somewhat higher r_s value of 0.47 was obtained between SCC and depth for the study's ponded segments. This transverse correlation was then additionally upgraded after a further removal of the upper Poplar (station VIP) and the Middle Fork (station VIII) data from the assessments because of their high substrate indexes and their low and non-patterned underwater CC percentages. This resulted in a separate evaluation of the ponded East Poplar segments, and it produced a much higher r_s figure of 0.79 in conjunction with this river's pronounced depth enhancements across the pools and the stream's comparatively small substrate indexes and variations.

As a final manipulation, a significantly high r_s of 0.87 was obtained when only the upper and middle East Poplar reaches were considered with their relatively fine-grained substrate compositions and their high CC levels. This last assessment erases the lower East Poplar station from the evaluation with its more moderate SCC percentages and its somewhat large substrate indexes. The high submersant WCC and depth coefficient of this terminal correlation in association with the East Poplar's deep waters and high CC's then generally points to the importance of an adequate stream depth for the establishment and development of a high abundance characteristic in a stream's underwater vegetation.

The adverse effects of reduced water levels on the submersant macrophytes, or from another perspective, the beneficial influences of increased stream depth on SCC, can be additionally illustrated for the project data through the application of rank correlations between the study sectors' underwater WCC percentages and the sectors' average depths for the three E-NE, IE-IM, and NM-M longitudinal bands of the inventory stations. Statistically significant and relatively high positive coefficients were calculated for each of these data sets with r_s values of 0.57, 0.64, and 0.58 respectively. These evaluations, thereby, also indicate that the stream sectors having the more highly ranked depth readings tended to have the more highly ranked submersant CC percentages. As a result, a positive relationship between SCC and depth became evident in the rivers from both a transverse and a longitudinal viewpoint when wading across a stream or when walking up and down a drainage course. However, the evaluations from the sequential cross-stream depth correlations that were described above suggest that the occurrence of a harsh substrate composition could significantly detract from the potential submersant WCC percentages that might have become established in a ponded reach on the basis of its depth characteristics.

Substrate and Submersant Abundance Relationships. The detrimental influence of a coarse bottom material on the underwater CC percentages of the Poplar basin was confirmed statistically by conducting longitudinal rank correlations between the submersant WCC percentages and the substrate reference numbers of the three longitudinal sector bands of the different sampling stations. Pronounced negative coefficients were obtained for the two deep water bands where the submersant macrophytes were most abundant, and these coefficients were statistically significant at less than 1% with r_s readings of -0.62 and -0.68 for the eighteen number pairs in the IE-IM and NM-M components respectively. But the substrate-SCC coefficient for the E-NE band where the submersants demonstrated low abundances in response to the shallow waters was insignificant with an r_s value of 0.15. Except for the near shore sectors therefore, the lower ranked SCC levels were typically obtained from those stream locations having a relatively high proportion of the gravel and rock streambed materials and a highly ranked substrate index number.

The negative significance of the longitudinal substrate coefficients for the deep water bands indicates that the increasing coarseness of the bottom materials that occurred at most of the stations in a transverse direction across the streams (Table 14) could also have acted to reduce submersant abundance levels towards the center of a reach, and this effect was possibly reflected in the midstream drops in SCC that were observed within many of the inventory segments. However, this transversely negative influence of substrate cannot be illustrated or substantiated statistically via a simple correlation analysis because these effects would run counter to the cross-stream SCC enhancements that were derived from the increasing water depths. Thus, an overall transverse rank correlation between SCC and substrate index for all of the stations was found to be statistically insignificant ($r_s = 0.14$) even though some moderate substrate effects of this kind might be anticipated for the streams as shown by the negative longitudinal correlations.

Whatever the case, the distinct edge to near middle increases in underwater CC's that were observed to occur at those ponded sites with the finer-grained substrate compositions (e.g., stations II, III, and IV) indicate that the beneifical effects that were derived from the midstream depth enhancements would far outweigh any small adverse impacts that might have been related to the somewhat higher substrate reference numbers that were commonly measured towards the center of a reach. Nonetheless, the relatively low SCC percentages that were tabulated for those stations having the coarser substrates (e.g., station V and the non-East Fork sites) definitely point to the marked negative influences that this physical variable can have on the submersant plants.

To a large degree, the magnitude of underwater canopy cover (and emergent CC) that was developed at any Poplar stream location was dependent upon both the location's depth and its substrate composition, and low SCC percentages were consistently secured from the shallow waters such as the riffle and near shore sections regardless of the substrate texture; but low SCC's were also always obtained in the presence of a coarse bottom material in spite of the water levels at that particular spot in the stream. With reference to the emergent vegetation, low ECC's were obtained in the deeper waters such as the midstream sections of the pools regardless of substrate type, and low ECC's were also measured on the coarser substrates even in the presence of a shallow stream depth.

Effects of Current on Submersant Abundance. Statistically insignificant longitudinal rank correlation coefficients were obtained between current velocity and submersant WCC for the deep water, IE-IM and NM-M sector bands of the sites ($r_s = -0.25$ and -0.05 respectively) where the underwater plants provided their greatest abundance levels. Similar to the emergents, therefore, current speeds at the relatively low values that were measured in the Poplar streams did not appear to have a pronounced influence on submersant growth, and this feature was especially true in the face of the marked effects that were produced by the depth and substrate variations of the drainage. As a result, the transverse simple correlations between velocity and SCC were largely meaningless because any adverse effects from increased velocity would run in opposition to the pronounced underwater plant abundance enhancements that were derived from the increasing depths toward the center of the streams where the highest velocities were also measured in the inventory segments. Velocity, thereby, within the context of the study region, probably exerted a quite subtle influence on both the emergent and submersant associations of the Poplar basin.

In the first place, such velocity effects would most likely be nonbeneficial rather than beneficial in character for most of the comparisons, and it would involve the potential for causing rather minor reductions in ECC or SCC as suggested by the small but negative rank correlation coefficients that were typically obtained for the particular longitudinal bands where the emergents or submersants were observed to be the most abundant. Thus, the mid-river drop in SCC that was noted for many of the stations could have been related in part to the higher current speeds that were measured for the NM and M sectors of the streams. But these r_s values could not be shown to be statistically significant at a high level of confidence. For example, the IE-IM longitudinal rank correlation between velocity and ECC ($r_s = -0.30$) was significant at only about 10%, while the other negative SCC and ECC r_s's provided even lower significance levels. Thus, if this type of adverse physical effect was operable on the plant canopy cover percentages of the Poplar drainage streams, it cannot be confirmed statistically by using the method of data analysis that was adopted in preparation to developing this baseline report.

One exception to the possible inverse and minor effect of current speed on aquatic plant abundance in the Poplar region was found with reference to the sparse submersant vegetation in the near shore longitudinal band of the stations where a statistically significant (at about 5%) and positive rank correlation was obtained between underwater WCC and velocity with $r_s = 0.39$ in this one evaluation. This correlation suggests that the higher ranked submersant CC's in the E-NE sectors (approaching a ranking of one) were most commonly obtained in conjunction with the higher velocity readings of these locations. However, this relationship represents a unique case for the study region because of the low SCC percentages and the relatively low velocity readings of these near shore stream positions. So even in this instance, any underwater CC effects that developed because of a higher E-NE velocity were undoubtedly quite minor in nature in comparison to the submersant abundance enhancements that were related to the occurrence of a greater water depth.

Effects of Current on Taxa Compositon. Another potential effect of increased current velocities on the plant communities of the Poplar streams involved a change in taxa abundance compositions along a cross-stream or longitudinal current gradient, and the most obvious example of such a floral shift was found in the intermediate sectors to middle stream sectors exchange in the abundance levels of *Myriophyllum spicatum* and *Potamogeton pectinatus*. *M. spicatum* tended to be most abundant in the less currented and intermediate stream positions with the lower milfoil CC's noted for the "fast-water" middle sections. *P. pecinatus*, in contrast, tended to be most prevalent in the rivers' more central sectors in association with the midstream's quicker current velocities and its reduced milfoil competition. This physical-taxa abundance interrelationship, in turn, was reflected by the differing current velocity optimums of the two submersant species with *P. pectinatus* providing the much higher fps value, and this interrelationship was also outlined by the WCC-velocity rank correlation coefficients of the two plants with *M. spicatum* showing a negative response to current ($r_s = -0.47$) as might be expected but with *P. pectinatus* apparently not affected by this variable in having an insignificant r_s value (0.15).

In general, the current velocities that happen to characterize the Poplar drainage waters appeared to be of an insufficient magnitude to markedly influence as a single affecting factor the establishment and abundance of the underwater macrophyte associations within the study region. But this physical variable did evoke some subtle influences on these plant assemblages by altering some aspects of their floral compositions and by possibly lowering their CC levels to some small degree at specific stream locations. Other examples of a velocity-induced floral change would include the bottom algae-floating algae variations and the down-drainage declines in arrowhead abundance, but the effects of depth and substrate on the Poplar plant communities were, of course, much more far-reaching than those of current speed.

Physical Factor and Emergent-Submersant Abundance Relationships. A rank correlation between SCC and ECC for the deep water, NM-M longitudinal band of the sampling sites indicates that the variations in the upstream-downstream abundance levels of the two plant associations within this part of the river were largely independent of each other with a low and insignificant r_s value of 0.02, and this non-correlation was in accord with the low ECC ratings of these midstream sectors. The total E + S CC percentages of the NM-M sectors, therefore, were primarily dependent upon the abundance levels of the submersant plants which were highly dominant in these mid-river positions, and an extremely high r_s value of 0.98 was obtained between total CC and SCC in this particular comparison. In contrast, the r_s coefficient between total CC and ECC (0.15) was shown to be statistically insignificant. As a result, the relationships between total plant abundance and the physical factors in this NM-M band were closely similar to the relationships of this kind that were described for the underwater vegetation with a significant total CC and depth r_s of 0.56, a significant substrate r_s of -0.74, and a low and insignificant velocity r_s of -0.009.

The levels of submersant and emergent CC were again observed to be independent of each other through the moderately deep and intermediate longitudinal band of the stations, and a low insignificant SCC-ECC r_s value of 0.16 was calculated for the IE-IM locations. But in this instance, the total CC percentages were partially dependent upon the abundance levels of the out-of-water plants with a statistically significant r_s of 0.52 established for the total CC and ECC variables. However, total plant abundance through the IE and IM sectors was additionally dependent to a large degree upon the CC's of the underwater plants as was noted for the midstream positions, and a high and statistically significant total CC-SCC r_s value of 0.88 was obtained for these intermediate stream sections along the appraisal sites. Thus, the response of total CC to the three physical factors in the intermediate part of the rivers was basically a combination of the separate responses to these factors of the two associations as follows: a significant depth and total CC r_s of 0.51, a significant substrate r_s of -0.84, and a velocity r_s of -0.35 that was statistically significant at about 10%.

In opposition to the deep water, IE to M sectors, the SCC and ECC plant variables were found to be inversely related in the shallow near shore longitudinal band of the streams with a statistically significant and negative r_s value of -0.42 for this comparison. Thus, the higher ranked SCC readings in the shallow parts of the rivers were obtained in conjunction with the lower ECC percentages and a reduced biotic competition from the emergent forms. But because of the extremely low SCC's that were always secured from the near shore locations, such emergent-linked abundance variations in the submersant macrophytes were generally quite small.

The above evaluation suggests that the magnitude of total macrophytic canopy cover along the E and NE band of the stations was primarily dependent upon the CC's of the emergent plants, and this observation was confirmed by the highly significant and positive ECC-total CC r_s value (0.88) of the shallow river sections. Contrariwise, an insignificant r_s between SCC and total CC (-0.07) was calculated for these same E-NE sectors. Because of this fact, the responses of the total CC expression to the physical variations that occurred along the E-NE band were generally similar to those that were observed for the emergent vegetation.

That is, variations in the shallow depths and low current speeds of the near shore Poplar waters did not appreciably affect the total E + S canopy cover levels of the streams' E and NE sectors, and insignificant rank correlation coefficients of 0.28 and -0.14 respectively were obtained in these two cases. But the substrate compositions of the E and NE sectors did demonstrate a significant effect on the total CC variable, and the r_s value in this instance was equal to -0.89. The higher macrophyte canopy covers in the shallow waters, thereby, were generally obtained in association with the finer-grained substrates which had a high proportion of the silts and mucks and a low and a more lowly ranked substrate index number (e.g., a ranking of fifteen for the E index of 1.09 at station I). The coarser substrates were then typically associated with the lower total plant abundance levels.

Effects of Depth, Substrate, and Current on Total Plant Abundance. As indicated by the above correlation analyses, the more highly ranked total CC percentages in the deep water IE to M sectors were typically measured in conjunction with the greater depths because of the marked positive responses of the more dominant submersant plants to the increasing levels of this variable. Although the emergent plants did not demonstrate a significant reaction to depth within any of the longitudinal bands up and down the streams, the negative responses of the emergents to this factor were illustrated by the cross-stream decreases in ECC that were correspondent to the enhanced water levels of the more central sectors. As a result, the emergent and submersant CC expressions demonstrated an inverse relationship when looking across the rivers in a transverse direction. The transverse r_s value between ECC and SCC was equal to -0.36 for all of the stations, and it was equal to -0.76 for the ponded East Poplar segments where the cross-stream patterns of change in the two plant variables were much more well defined.

The two components of the total canopy cover expression essentially provided antagonistic cross-stream reactions to the same depth factor, and this feature formed the basis for the inter-association CC compensations that were noted for the Poplar streams. In other words, the high abundances of the emergents in the shallow waters acted to compensate for the low CC's of the underwater plants at these same locations, and the opposite was observed to be true for the deeper stream positions. Because of this compensation, the total CC percentages that were obtained from the inventory demonstrated a smaller variation and a more constant level across the streams and among the stations than either of its ECC or SCC components. An illustration of this lower total plant abundance variability among the sampling sites was found in the WCC standard deviation/WCC mean ratios of the stations which were equal to 96.5%, 76.7%, and 68.6% for the emergents, submersants, and the total E + S canopy cover summation respectively.

However, such biotic CC compensations between the two macrophytic associations were not observed to be perfectly balanced, and the underwater plants tended to afford higher CC's under their ideal deep water conditions than the CC's that were provided by the emergent plants in the shallower parts of the streams. This aspect is illustrated by the greater submersant over emergent WCC means that were calculated for all of the stations; these averages were equal to 25.2% for the submersants and 13.9% for the emergents with a total CC mean of 39.1%. Because of this incomplete compensation, the total plant abundance expression was observed to be directly related to depth on an all-station basis as a result of the positive responses of the more prevalent submersant forms to this variable, and a statistically significant r_s coefficient between the overall E + S station CC's and the average station depths was established at 0.65 for the nine possible site comparisons. Thus the stations that had the greater overall depths most commonly had the more highly ranked total CC levels as calculated with reference to an entire inventory segment.

An evaluation of total canopy cover and substrate proved to be much more straightforward than that of depth because of the similar emergent and submersant responses to this variable, and distinctively low total CC's were obtained in association with the coarser bottom materials and the higher ranked substrate index numbers because of the marked negative reactions of both the underwater and out-of-water vegetation to this particular affecting factor. The adverse effects of the coarser substrates on total plant abundance were quite obvious in a longitudinal direction up and down the streams and in a transverse direction across the rivers, and a statistically significant and negative cross-stream r_s value of -0.40 was calculated between the substrate indexes and the total CC's of the E to M sectors of all of the sites. As a result, the negative all-station r_s between the average station indexes and the sites' overall total CC's was also quite pronounced with a rank coefficient of -0.77 for the nine possible combinations. The inventory segments with the higher ranked average index values, thereby, typically provided the lower overall total CC percentages.

In contrast to substrate and depth, the current velocities of the Poplar drainage streams were of an insufficient magnitude to exert a major influence on the total plant abundance characteristics of the basin's aquatic plant communities because of the reduced effects of velocity on the communities' emergent and submersant components. Slight reductions in total CC might be anticipated in those stream locations having the higher velocity measurements as suggested by the low negative r_s value between this variable and the stations' total CC readings. However, such meager potential plant responses to current speed could not be shown to be statistically significant at a high degree of confidence via a simple rank correlation assessment, and an all-station correlation between overall total CC and this physical factor was also insignificant with a small and negative r_s of -0.15 for the nine appraisal sites. Thus, only extremely minor total CC alterations might be expected to stem from the types of variations in stream velocity that were observed for the inventory waters.

But if the current velocities of the Poplar drainage streams should happen to increase for some reason beyond the range that was measured in the present study, then this physical variable could develop a much more pronounced influence over the region's macrophyte communities. Such enhanced velocities would tend to favor the periphytic and bottom algal forms, and they would probably cause some level of proportional degradation in the higher aquatic plant assemblages, particularly with respect to the dense milfoil stands.

Physical Factor and Total Plant Abundance Relationships: An Overview. In the main, and in light of the present morphometric status of the Poplar rivers, the substrate make-up of a stream location, by affecting both the emergent and the submersant associations, appeared to be the principal physical factor that controlled total plant abundance features through the Poplar basin. Current velocity, in contrast, showed a much more negligible effect.

Of the twenty-three stream sectors showing the highest total abundances with WCC's greater than 50%, thirteen had substrate reference numbers less than 1.5 units with this index range pointing to a muck and silt composition. But only three of these high abundance sectors had substrate indexes greater than the 2.0 level which describes a sandier composition with the possible occurrence of some gravel materials. Of the twenty-one sectors showing the lowest total abundances with WCC's less than 20%, all had a substrate index greater than 2.0 units, and seventeen had substrate reference numbers greater than the 3.0 level where the gravels and rocks would begin to predominate. However, none of the high abundance sectors provided index values greater than 3.0 units, and these comparisons additionally delineate the importance of substrate as an affecting factor in the Poplar system.

In addition to substrate, the presence of a decreased water depth would be expected to reduce total CC to some extent because of the incomplete compensation of the emergent plants for the lower submersant abundances that developed in the shallow waters. But because of the occurrence of a partial emergent-submersant compensation, the effect of depth on total CC was less pronounced than the effects that were related to the nature of the bottom materials. The exact influence of depth on the total plant abundance characteristics of any stream location with the other factors held constant was essentially dependent upon the particular blend of CC enhancement and CC detraction that was derived from a certain level of water with respect to the submersant and emergent associations respectively. But on a general basis, the higher total abundances were most commonly obtained from the deeper waters.

For example, of the twenty-three stream sectors showing the highest E + S WCC percentages, 61% had depths greater than one foot with 30% and 4% providing depths greater than 1.5 and two feet, but only 17% of these sectors had depths at less than 0.5 feet. In contrast, of the twenty-one sectors showing the lowest E + S WCC values, only 38% had depths greater than one foot with only 10% and zero percent of the low abundance sectors providing depths greater than 1.5 and two feet. However, 38% of these low WCC sectors did have depths at less than 0.5 feet.

As an alternate example, of the sectors having the fairly deep waters in excess of one foot, 58% had the high total WCC's above 50% while only 33%

had the lower total WCC values below 20%; the remaining sectors of this kind demonstrated intermediate WCC percentages. In contrast, of the stream sectors having the shallower waters at less than one foot, only 30% demonstrated a high total WCC level, while 43% and 27% presented low and intermediate plant abundance values respectively. These percentage comparisons further indicate that an enhancement of the water levels in a stream reach would tend to elevate total aquatic plant abundance levels to some degree in the case that the other potential affecting factors were non-changing or non-influential within the system.

NON-EAST POPLAR INVENTORY SEGMENTS--STATIONS VI AND VII

Community Characteristics

Mainstem Site Location, Rationale, and Physical Aspects. Since the aquatic biota of the East Poplar River will receive the major brunt of any environmental effects that might result from the closure of Morrison Dam (Figure 1), the main effort of the Poplar basin macrophyte study was directed to this one particular stream. However, two other stream reaches apart from the East Poplar were examined at single locations in order to form the basis for intra-inventory and future inter-inventory comparisons between the affected and non-affected, or at least the less-affected, waters of the region under the assumption that post-closure macrophyte surveys will be eventually completed on the rivers in the next several years. Such inter-inventory comparisons will provide the means for detecting the development of any impoundment-related changes that might occur in the basin's aquatic plant communities.

One of the two non-East Fork stations that were assessed during the baseline survey was located on the upper Poplar River mainstem south of Scobey, Montana about 7.3 direct miles (approximately twelve river miles) below the confluence of the East and Middle Forks (Figure 1) and about 120 to 320 yards downstream of the first Highway 13 bridge below the town. This portion of the mainstem had an extensive ponded segment that was somewhat wider and slightly shallower than the typical East Fork pools with slower current speeds and with significantly coarser substrates than most of the East Poplar sections. The main objective for sampling at this ponded main Poplar site (station VIP) was to provide a means for evaluating any down-drainage migrations of the East Poplar's dense macrophyte communities from the eastern fork into the main river.

As was the case for the initial baseline assessment, a downstream macrophyte reconnaissance of the main Poplar below the station VIP location should be undertaken in any future surveys in order to supplement the main monitoring effort, and additional appraisal sites might be eventually established on the lower ports of the mainstem as a means of quantifying the development of pronounced macrophytic growths. At the time of the first inventory, the lower Poplar was largely devoid of any submersant higher plant taxa.

A riffle segment in close vicinity of the ponded reach was also inventoried on the upper Poplar mainstem. This riffle segment (station VIR), of course, had markedly different physical characteristics from the nearby station VI pools in being narrower and much shallower with more rapid current speeds. In addition, the VR riffle had a somewhat coarser overall substrate composition than the VIP reach, although this was not the case for all of the sectors.

The VIR segment was also somewhat different physically from the riffle on the lower East Poplar (station V), and wider transects and shallower waters were evaluated across all of the riffle sectors on the mainstem side. Furthermore, station VIR demonstrated lower current velocities and slightly less coarse substrates with lower index numbers than the VR stretch through most of the sampling locations. Such inter-riffle and riffle-pool physical discrepancies would be expected to be reflected by variations in the abundance characteristics of the separate plant communities.

The vegetative data that were obtained from the main river riffle site are presented in Table 21, and the plant data that were collected from the ponded segment on the mainstem are summarized in Table 22.

Middle Fork Site Location, Rationale, and Physical Aspects. The second non-East Fork site was located on the Middle Fork of the Poplar River about twelve miles northwest of Scobey near the town of Four Buttes, Montana. Along with providing a general means for judging the nature of the East Poplar vegetation in relation to the other streams of the drainage, another objective for sampling on the Middle Fork, which is not affected by the Cookson impoundment, is to afford a frame of reference for separating those vegetational changes in the East Poplar that might have been caused by the upstream impoundment from the natural variations that probably occur in the basin's aquatic plant communities as a result of in situ and non-impoundment factors. Such normal year-to-year vegetative changes in the streams can then be separated from the impoundment effects through the inter-inventory comparisons of the East Poplar data to the data that are obtained from the non-affected Middle Fork reach.

If the East and Middle Forks should happen to demonstrate through these comparisons somewhat similar trends of vegetative change on a relative basis, then at least those parts of the plant community alterations occurring in the East Poplar between survey periods that corresponded to the Middle Fork variations would be attributable to the inherent cyclic variations of the system instead of being entirely caused by any environmental effects that might emanate from the upstream reservoir. But the occurrence of non-comparable residual changes that might be left over in the East Poplar would point to the possible action of some outside influences. On the other hand, the observation of East Fork vegetative alterations between inventory periods that stand in contrast to a general Middle Fork stability or to a nonparallel Middle Fork variation would also function to point to the development of environmental effects that could potentially stem from the Coronach impoundment. The Middle Fork site, therefore, was basically intended to serve as a control station which can be used for comparative purposes when making the data assessments that would be associated with any future macrophyte surveys that might be undertaken in the Poplar region.

Similar to station IV on the East Poplar River, station VII on the Middle Fork was placed in a roughly midway position on the Middle Fork's Montana reach so that the site was about equidistant from the international boundary and the river's confluence near Scobey with the basin's more eastern

Table 21. Summary of aquatic macrophyte data: main Poplar River south of Scobey (station VI-*riffle*).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E *Carex*	2.78	27.78	0.48	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.45	4.55	0.55	5.47	55.6	1.00
E *Scirpus*	0.56	5.56	0.48	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	1.56	11.1	1.00
E Poaceae	0.56	5.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.78	11.1	1.00
E *Hipp*.	1.67	16.67	0.48	4.76	0.00	0.00	2.00	8.00	1.14	4.55	0.00	0.00	0.90	5.47	44.4	1.64
S *Hipp*.	0.00	0.00	0.95	9.52	0.00	0.00	5.20	24.00	4.32	18.18	0.00	0.00	1.91	9.38	44.4	2.04
S *Myr*.	0.56	5.56	2.86	28.57	2.00	20.00	4.80	32.00	3.18	13.64	0.45	4.55	2.42	17.97	100.	1.35
S *P. fil*.	0.56	5.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.78	11.1	1.00
S *P. pec*.	0.00	0.00	0.00	0.00	0.50	5.00	0.40	4.00	0.45	4.55	0.00	0.00	0.23	2.34	33.3	1.00
S. *Zan*.	0.00	0.00	2.86	9.52	1.00	10.00	0.80	8.00	0.91	9.09	0.45	4.55	1.02	7.03	55.6	1.44
B. Algae	2.22	22.22	3.33	14.29	3.50	15.00	1.20	12.00	1.82	18.18	2.73	9.09	2.42	14.84	77.8	1.63
F. Algae	1.67	16.67	3.81	19.05	2.50	5.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	6.25	44.4	2.00
Total CC	10.55	105.56	15.23	95.24	9.50	55.00	14.40	88.00	11.82	68.18	4.09	22.73	11.02	71.88	--	1.53
E CC	5.56	55.56	1.43	14.29	0.00	0.00	2.00	8.00	1.14	4.55	0.45	4.55	1.68	13.28	--	1.26
S CC	5.00	50.00	13.81	80.95	9.50	55.00	12.40	80.00	10.68	63.64	3.64	18.18	9.34	58.59	--	1.59
Veg. CC	77.78	77.78	76.19	76.19	45.00	45.00	68.00	68.00	45.45	45.45	27.27	27.27	56.25	56.25	--	--
Bare Sub.	22.22	22.22	23.81	23.81	55.00	55.00	32.00	32.00	54.55	54.55	72.73	72.73	43.75	43.75	100.	--
Bare-Alg.	44.44	44.44	42.86	42.86	75.00	75.00	40.00	40.00	72.73	72.73	81.82	81.82	59.38	59.38	--	--
ABio	--	1.00	--	1.60	--	1.73	--	1.64	--	1.73	--	1.80	--	1.53	--	--
Taxa/Pt.	--	1.36	--	1.25	--	1.22	--	1.38	--	1.67	--	1.00	--	1.33	--	--

Table 22. Summary of aquatic macrophyte data: main Poplar River south of Scobey (station VI-pool).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E Carex	4.21	31.58	1.35	5.77	0.36	3.64	0.42	4.17	0.20	2.00	1.15	3.85	1.15	7.46	57.9	1.55
E Scirpus	0.26	2.63	0.19	1.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.68	5.3	1.00
E Eleoch.	3.95	28.95	1.35	5.77	0.18	1.82	0.21	2.08	0.20	2.00	0.38	3.85	0.92	6.44	57.9	1.42
E Poaceae	0.53	5.26	0.19	1.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.02	10.5	1.00
E Hipp.	1.32	15.79	0.29	3.85	0.18	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.25	3.05	42.1	0.83
S Hipp.	0.79	10.53	0.87	9.62	1.45	7.27	0.21	2.08	0.00	0.00	0.00	0.00	0.56	4.75	52.6	1.18
S Myr.	0.26	2.63	6.15	46.15	3.82	30.91	1.04	10.42	0.20	2.00	0.00	0.00	2.03	16.27	84.2	1.25
S P. fil.	0.00	0.00	0.19	1.92	0.18	1.82	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.68	10.5	1.00
S P. pec.	0.26	2.63	0.96	9.62	0.36	3.64	0.00	0.00	0.20	2.00	0.00	0.00	0.31	3.05	36.8	1.00
S Zan.	0.53	5.26	0.77	7.69	0.00	0.00	0.42	4.17	0.00	0.00	0.00	0.00	0.27	2.71	26.3	1.00
B. Algae	0.00	0.00	0.58	5.77	1.09	3.64	1.25	4.17	0.20	2.00	0.00	0.00	0.54	2.71	21.1	2.00
F. Algae	6.32	42.11	1.92	19.23	0.18	1.82	0.00	0.00	0.20	2.00	0.00	0.00	1.22	9.49	68.4	1.29
Total CC	18.42	147.37	14.81	119.23	7.82	56.36	3.54	27.08	1.20	12.00	1.54	7.69	7.49	58.31	--	1.28
E CC	10.26	84.21	3.37	19.23	0.73	7.27	0.63	6.25	0.40	4.00	1.54	7.69	2.49	18.64	--	1.34
S CC	8.16	63.16	11.44	100.00	7.09	49.09	2.92	20.83	0.80	8.00	0.00	0.00	5.00	39.66	--	1.26
Veg. CC	86.84	86.84	67.31	67.31	43.64	43.64	20.83	20.83	6.00	6.00	3.85	3.85	36.27	36.27	--	--
Bare Sub.	13.16	13.16	32.69	32.69	56.36	56.36	79.17	79.17	94.00	94.00	96.15	96.15	63.73	63.73	100.	--
Bare-Alg.	26.32	26.32	38.46	38.46	61.82	61.82	81.25	81.25	96.00	96.00	96.15	96.15	68.14	68.14	--	--
ABio	--	1.25	--	1.24	--	1.39	--	1.31	--	1.00	--	2.00	--	1.28	--	--
Taxa/Pt.	--	1.70	--	1.77	--	1.29	--	1.30	--	2.00	--	2.00	--	1.61	--	--

stream (Figure 1). The Middle Fork station was located about 7.5 miles north of Four Buttes and approximately nine direct miles southeast of the spot where the river crosses the United States-Canadian border. A distinct riffle section could not be found at this site, and the stream's ponded section through the inventory reach was observed to be somewhat different physically from the pools that were typically sampled through most of the East Poplar and the Poplar mainstem.

Like the case for station I, the station VII Middle Fork segment, with its pronounced stream banks and relatively deep near shore sectors, was somewhat channel-like in character as a result of its narrow widths and comparatively shallow waters towards the center of the stream. But the Middle Fork was definitely pool-like because of its low current velocities. The station VII reach provided coarser substrates than ponded East Poplar segments, and its bottom materials were less harsh than the substrates of the main river. The Middle Fork substrate reference numbers, thereby, were intermediate between the indexes obtained from the East Poplar pools and those of the station VIP reach across all of the sectors. The vegetative data that were collected from this Middle Fork site are presented in Table 23.

In order to facilitate and enhance the Middle Fork and East Poplar vegetative comparisons, two additional stations on the Middle Fork might be profitably incorporated into the future macrophyte surveys of the drainage as a means of complimenting the data that are obtained from the river's midway site which was examined during this initial inventory. These added stations would then be sampled in concert with the middle river location. One of these extra appraisal sites could be established on the upper Middle Fork in the vicinity of the international border, while the other could be placed on the lower Middle Fork reach in the vicinity of the stream's confluence with the East Poplar River. However, the lack of a ready physical access to these proposed Middle Fork stations, particularly with reference to the border position, might preclude their evaluation if time constraints should prove to be a major consideration in the subsequent inventory work.

But if the upper and lower Middle Fork sites can be assessed at some future date, then these expanded sets of water quality, physical, plant information will provide the option for analyzing the downstream vegetative changes that occur along the East Fork in relation to those that occur along a middle drainage and non-impounded portion of the Poplar system. Such comparisons of the downstream variations in the Middle Fork and East Fork plant communities, and considerations of how such variations might change from year to year in one stream with reference to the other, should afford some further insights into the types and degree of vegetative alterations that might be initiated in the East Poplar River of Montana as a result of forming the Cookson Reservoir and constructing the power generation facilities on the Canadian side of this more eastern basin stream.

Mainstem Abundance Rankings and East Fork Comparisons. Since the East Poplar appraisal sites formed the core of interest for this initial macrophyte survey, a great deal of attention will not be directed in this report to descriptions of the aquatic plant communities that were examined at the two accessory, non-East Fork sampling stations. Furthermore, the vegetative data that were obtained from these non-East Fork locations do

Table 23. Summary of aquatic macrophyte data: Middle Fork Poplar River near Four Buttes (station VII).

	Weighted and True Percent Canopy Cover															
	by Stream Sector												by Station			
	Edge		Near Edge		IE		IM		Near Middle		Middle					
Taxa	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	WCC	TCC	TF	ABio
E Carex	9.63	44.44	3.13	22.92	2.42	11.29	0.41	4.05	0.00	0.00	0.00	0.00	2.34	12.40	88.9	1.89
E Juncus	0.37	3.70	0.21	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.83	11.1	1.00
E Scirpus	0.56	5.56	0.42	4.17	0.00	0.00	0.14	1.35	0.00	0.00	0.00	0.00	0.17	1.65	11.1	1.00
E Eleoch.	3.15	16.67	0.83	8.33	0.65	6.45	0.27	2.70	0.00	0.00	0.00	0.00	0.74	5.23	40.7	1.42
E Poaceae	1.30	12.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	1.93	25.9	1.00
S Poaceae	0.00	0.00	0.21	2.08	0.16	1.61	0.14	1.35	0.17	1.72	0.00	0.00	0.11	1.10	14.8	1.00
E Hipp.	0.19	1.85	0.21	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.55	7.4	1.00
S Char.	0.00	0.00	1.04	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.28	3.7	5.00
S Myr.	1.48	7.41	5.00	25.00	5.81	37.10	7.83	28.38	4.66	25.86	4.18	17.91	4.99	23.97	92.6	2.08
S P. fil.	0.19	1.85	0.00	0.00	0.00	0.00	0.00	0.00	0.17	1.72	0.15	1.49	0.08	0.83	3.7	1.00
S P. fol.	0.00	0.00	0.42	4.17	0.97	3.23	1.08	5.41	0.17	1.72	2.69	8.96	0.96	4.13	25.9	2.33
S P. pec.	0.00	0.00	0.83	8.33	2.90	9.68	3.51	18.92	3.10	17.24	1.34	13.43	2.07	11.85	59.3	1.74
S Zan.	0.00	0.00	0.21	2.08	0.00	0.00	0.14	1.35	0.00	0.00	0.00	0.00	0.06	0.55	11.1	1.00
B. Algae	0.00	0.00	0.00	0.00	0.32	3.23	0.68	1.35	0.00	0.00	0.00	0.00	0.19	0.83	11.1	2.33
F. Algae	1.48	14.81	2.50	8.33	2.26	9.68	2.57	9.46	0.00	0.00	0.00	0.00	1.46	6.88	40.7	2.12
Total CC	18.33	109.26	15.00	91.67	15.48	82.26	16.76	74.32	8.28	48.28	8.36	41.79	13.64	73.00	--	1.87
E CC	15.19	85.19	4.79	39.58	3.06	17.74	0.81	8.11	0.00	0.00	0.00	0.00	3.58	22.59	--	1.59
S CC	3.15	24.07	10.21	52.08	12.42	64.52	15.95	66.22	8.28	48.28	8.36	41.79	10.06	50.41	--	1.99
Veg. CC	72.22	72.22	56.25	56.25	54.84	54.84	50.00	50.00	41.38	41.38	34.33	34.33	50.68	50.69	--	--
Bare Sub.	27.78	27.78	43.75	43.75	45.16	45.16	50.00	50.00	58.62	58.62	65.67	65.67	49.31	49.31	100.	--
Bare-Alg.	29.63	29.63	43.75	43.75	50.00	50.00	52.70	52.70	58.62	58.62	65.67	65.67	50.96	50.96	--	--
ABio	--	1.68	--	1.64	--	1.88	--	2.25	--	1.71	--	2.00	--	1.87	--	--
Taxa/Pt.	--	1.51	--	1.63	--	1.50	--	1.49	--	1.27	--	1.27	--	1.46	--	--

not provide for an extensive reference base for descriptive purposes because of the low viability and general paucity of the macrophyte assemblages in the Poplar mainstem and the Middle Fork segments.

As indicated in Tables 21 and 22, the most distinctive botanical feature of the mainstem site was found to reside in its extremely low canopy cover percentages in both the riffle and ponded segments, and a marked decline in this plant variable was noted from the lower East Poplar into the main river through both of these sections and in both the emergent and the submersant associations. As a result, station VIR afforded ninth (last), eighth, and eighth place rankings among the sites in terms of its total emergent, total submersant, and total E + S WCC abundances respectively while station VIP afforded eighth, ninth, and ninth place rankings for these same three vegetative components. These observations suggest that the station VI position on the main river was very near the outer fringe of the down-drainage range of the basin's aquatic macrophytes with the Poplar River generally lacking in any underwater higher plants at a position that was probably not too far below this up-river site.

In contrast to the marked pool to riffle differences in plant abundance that were observed at station V with the former exceeding the latter by a considerable margin, the riffle reach at station VI actually provided a slightly higher E + S CC for the site than its ponded segment because of a greater submersant prevalence in the station's riffle section. Thus, the station V to station VI decrease in CC was most pronounced through the ponded locations with 78%, 86%, and 84% overall drops in the E, S, and E + S expressions respectively; smaller declines of 76%, 32%, and 47% were obtained for these components through the stations' riffles. As indicated by these percentages, the relative decline in ECC from site to site was observed to be fairly similar across the two kinds of stream morphometries, although the inter-station and downstream decreases in SCC, and thereby in total CC, were much more pronounced in the ponded versus the riffle segments. This suggests that the factors causing the lower East Poplar to mainstem declines in ECC were generally consistent between the riffles and the pools, while the factors causing the drops in SCC tended to be more intense in the ponded sections than in the riffle reaches.

Mainstem Evaluation of Affecting Factors: On-Site Features. The distinct 78% to 86% declines in ECC, SCC, and total CC between the station V and VI pools were probably related at least in part to the relatively distinct and consistent increases in the substrate index numbers that occurred from the lower East Poplar into the main river across all of the ponded sectors (Table 13). The slightly greater SCC and total CC percentages at station VIR over station VIP, however, cannot be related to substrate since the somewhat less coarse bottom materials of the ponded segment actually provided a slightly lower CC reading for these two plant variables. In addition, the 32% to 76% drops in plant abundance that were noted between the station V and VI riffles also cannot be readily attributed to any corresponding substrate changes, or to an increased current, because the substrate indexes of the VR and VIR reaches were within the same general range and were closely similar on an overall basis with the lower current velocities obtained from the station VIR locations. The station VR to VIR increases or decreases in the substrate indexes were dependent upon the particular stream sector, and these substrate differences were not very consistent or pronounced with reference to the entire station.

In the case of the riffles therefore, the decline in SCC and total CC from station VR to station VIR was most likely caused by the much shallower waters that were consistently measured in the VIR sectors (Table 11). Thus, the adverse effects on plant abundance that stemmed from the increasing substrate coarseness of the station V to VI pools proved to be much more intense, causing a greater amount of CC change, than the negative effects that were related to the reduced water depths of the station VIR reach.

In the case of the canopy cover differences between the station VI riffles and pools (Tables 21 and 22), the higher ECC values that were associated with the station's pools over its riffle segment were correlated with the less coarse substrates that were encountered in the shallow E and NE sectors of the deep water reach (Table 14). The greater SCC values of the riffles at station VI over the pools, in turn, were caused in part by the higher bottom algae tabulations of the riffle segment where a riffle environment would be more amenable to the ecesis of this macroalgal growth habit than the environment of a ponded section. Although the riffle to pool algal CC discrepancies at station VI and the algae's actual CC levels were relatively small, such minor differences were accentuated in this instance because of the station's low overall CC percentages.

But in addition to the bottom algae, several other underwater plants also demonstrated higher CC's in the station VI riffles versus its pools (e.g., Hippuris vulgaris and Zanichella palustris), and this feature then accounts for the rest of the inter-reach abundance differences. This relationship stands in opposition to the observations that were made at station V, and the exact reasons for the true macrophytes' higher CC percentages in the harsher riffle environment of the mainstem are largely unknown. Possibly the greater depths of the VIP reach in conjunction with the comparatively high turbidities of the main river (Table 8) resulted in some light transmission reductions that could have acted to retard macrophytic growth in the deeper ponded sectors of the stream with these light penetration problems not occurring in the shallow waters of the riffle reach.

As an added observation, the overall E + S CC levels at station VI were also higher in the riffles than in the pools. This discrepancy was due to the fact that the submersant plants demonstrated a greater riffle to pool discrepancy favoring the riffle reach than the opposing riffle to pool discrepancy of the emergents which favored the ponded segment. The net effect of these CC differences was a higher total plant abundance level in the riffle reach, and on a total CC basis, the adverse aspects of the pools on the plants were somewhat more pronounced that the adverse aspects of the riffles.

Evaluation of Runoff Scouring as a Potential Affecting Factor. Although the greater coarseness of the station VIP substrates relative to those at station VP undoubtedly played a role in lowering the macrophytic CC percentages of the ponded mainstem site, the 1.5-fold increase in the average substrate reference numbers that occurred from station VP to station VIP did not appear to be of an adequate magnitude to entirely account for the pronounced 5.2-fold decrease in total plant abundance that was observed between these same two stations. Some other affecting factor, thereby, that was more influential in the main Poplar than in the East Fork appears to have had an additional effect on the macrophytes of the main river pools so as to have accentuated this down-drainage and East Poplar to main river drop in canopy cover. The scouring action and the bedload movement and redeposition that is derived from storm runoff events and the spring freshet might have had such a differential influence on the lower East Poplar and the mainstem segments because of the peak flow discrepancy that occurs between the two drainage locations.

These runoff effects would be much less severe in the East Fork than in the mainstem because of a water retention by the Cookson Reservoir, but they would still be fairly pronounced in the main river because of the runoff waters that are received from the Middle Fork reach and from other sources. For example, the maximum daily runoff flow that was measured during the spring season of the 1979 water year, which occurred in April (USGS, 1975-1979), was six-times greater in the Middle Fork than in the East Poplar River, and it was about twenty-times greater in the lower main Poplar than it was in the mainstem's eastern fork. Runoff scouring would also be sequentially enhanced downstream along the East Poplar in spite of the impoundment because of the occurrence of intermediate water inputs, and the Scobey USGS station on the lower East Poplar produced a nearly three-fold higher maximum daily spring runoff flow than the river's international boundary site. These enhanced downstream runoffs along the East Poplar, then, might be one of the causal factors for the occurrence of the lower macrophytic CC's that were tabulated for the lower stream reach (station V) versus the much higher tabulations that were made in most of the upstream segments (stations II to IV).

In a similar fashion, runoff scouring was also probably instrumental in reducing the plant abundance levels of the station VI riffle reach relative to the CC's that were measured at the VR location. This scouring action coupled with the runoff-related depth fluctuations of the near shore waters plus the presence of a coarse-grained substrate composition would seem to account in tandem for the extremely low abundances of the emergent associations at stations VIR and VIP. The potential effect of a down-drainage scouring for reducing the abundance levels of the emergent plants in the main river was quite consistent between the riffles and the pools with similar station V to station VI percentage decreases in the out-of-water WCC's of both of these morphometries. However, this same runoff factor appeared to have a greater effect on the submersant macrophytes of the mainstem pools than it had on the underwater plants of the station VI riffle section since a smaller station V to station VI percentage decline in the submersant WCC variable, and thereby in total WCC, was identified for the riffle reach.

But on a combined basis (i.e., the riffles plus the pools), the possible influences of runoff scouring were quite similar on both of the plant associations, and 71% to 77% drops in the combined ECC, SCC, and total CC percentages of the aquatic macrophytes became evident when going from station V to station VI. Thus marked changes in the plant community characteristics of the Poplar system occurred along a relatively narrow geographic span of the basin as a result of the down-drainage increases in the intensity of runoff scouring and as a result of the negative enhancements that were identified for some of the other environmental factors such as substrate coarseness. Furthermore, the coarse nature of the mainstem bottom materials was probably maintained through the action of a more intense spring flush in a downstream direction, and this observation points to the secondary and indirect importance of the basin's runoff events for controlling the establishment and growth of its hydrophytic vegetation. A further illustration of this potential influence is found when comparing the upper East Poplar to the upper Poplar mainstem where the rivers demonstrated an overall 90% decline in the total canopy cover levels of their aquatic plant assemblages through a fairly short eighteen mile distance between the appropriate sampling sites.

Middle Fork Abundance Rankings and East Fork-Mainstem Comparisons. The midway Middle Fork segment, like the upper Poplar mainstem reach, revealed comparatively low overall emergent, submersant, and total aquatic plant abundance levels (Table 23) that were intermediate between the canopy covers of stations VP and VIP but heavily skewed in all of the cases towards the extremely low CC values of the main river site. That is, the Middle Fork provided 1.4-, 2.0-, and 1.8-fold greater E, S, and E + S CC's than the station VIP section, while the lower East Poplar pools afforded 3.2-, 3.5-, and 3.4-fold greater CC's than the Middle Fork reach for these same plant categories. Thus the Middle Fork station was given consistent seventh place prevalence rankings among the nine sites for each of the three macrophytic components, and this middle drainage stream demonstrated much lower CC percentages than most of the East Poplar inventory locations.

The close correlation of the Middle Fork's intermediate CC percentages with the intermediate nature of the Middle Fork's substrate reference numbers, which were in between the indexes of stations VP and VIP across all of the sectors, suggests that the somewhat coarser nature of the Middle Fork's bottom materials acted to restrict the stream's macrophytic abundances relative to the abundance characteristics of the East Poplar River, although these CC retardations were less distinct than those of the upper mainstem reach. But similar to the mainstem observation, the 1.38-times higher mean substrate index value of station VII over the index average of station VP did not appear to be of an adequate magnitude to entirely account for the 3.2- to 3.5-fold lower plant CC's that were measured at the middle river station in relation to the higher CC levels that were recorded for the station V pools along the more eastern stream. As a result, the greater effect of runoff scouring in the Middle Fork versus the East Fork with the Middle Fork's higher peak volumes of spring season flow might be invoked as an added causal element to account for some of these inter-river canopy cover discrepancies.

As an additional factor, the generally lower depths of the Middle Fork site in comparison to most of the other ponded segments of the drainage (Table 11) might also have been influential in retarding submersant plant growths in the Middle Fork waters to some extent. But the low current velocities of the midway Middle Fork section were obviously not a major physical variable in adversely affecting the aquatic plant communities of this internal basin reach.

Middle Fork Abundance Variations. Similar to most of the East Poplar stations, the underwater vegetation at the Middle Fork site demonstrated an edge of water to IM sector increase in WCC with a subsequent decline in the submersants when moving towards the middle of the stream (Table 23). The emergent vegetation, in turn, revealed a consistent and transverse, edge to middle decline. But because of a biotic CC compensation between these two plant associations, the total plant abundance levels of station VII were observed to be fairly constant across the E to IM sectors with the occurrence of only some minor and non-patterned CC variations along this span. These compensations then broke-down towards the center of the fork, and a drop in total CC was observed in the NM and M sectors in accord with the midstream decline in SCC and in accord with the absence of any emergent vegetation from the more central river positions.

The transverse increases and decreases in SCC and ECC at station VII were probably related to the positive and negative responses of the underwater and out-of-water plants respectively to the increasing midstream depths of the river. Furthermore, the IM to M submersant declines and the edge to middle emergent declines in CC could also have been partially related to the increasing coarseness of the bottom materials towards the midpoint of the stream. However, the 1.11-fold IM to M increase in the substrate reference numbers of the Middle Fork site,which coincided with a 1.15-fold increase in stream depth, did not appear to be at an adequate level to entirely account for the distinct 1.9-fold drop in submersant WCC across the same three sectors. For comparison, the average 1.12-fold decline in the IM to M SCC percentages of the East Poplar pools, with a 1.25-fold increase in depth, was much more closely related to the mean 1.22 -fold elevation in the substrate indexes between the IM and M sectors of the East Fork stations.

The above substrate-abundance comparisons indicate that another environmental element in addition to substrate was probably adversely operable in the Middle Fork reach but largely noneffective in the East Poplar River. As one possibility, the relatively high turbidities of the Middle Fork waters (Table 8) could have restricted light transmissions in the somewhat deep, NM and M sectors to a sufficient extent so as to have retarded underwater macrophyte growth in these particular stream locations to some noticeable degree. The light transmission data of this study indicate this could have been the case as described previously, and parallels therefore existed between the inventory's physical data and its hydrophytic CC numbers which point to the likely influence of light transmission as an affecting factor on the submersants of the Middle Fork station. The low turbidities of the East Poplar River, in opposition, generally precluded the action of a reduced light penetration in retarding the stream's underwater plant abundance levels, and this feature was reflected by the closely comparable variations in the CC percentages and substrate indexes of the eastern fork's deep-water sectors.

As an alternate contributor to the Middle Fork-East Fork differences in the magnitude of the plant abundance changes across the IM to M sectors, the higher runoff volumes of the Middle Fork relative to the East Poplar could have possibly produced a more severe midstream versus closer-to-shore scouring effect on the Middle Fork vegetation than on the East Fork macrophytes, and this occurrence would be ultimately reflected by the more pronounced IM to M declines in CC that were noted for the middle drainage reach in comparison to the smaller inter-sector discrepancies that were observed for the impounded eastern fork. But the actual vegetative effects of such runoff events in the various study area streams cannot be definitely documented within the limitations of the inventory's data base, although these kinds of differential inter-station and intra-station influences do appear to be operable within the survey waters at some level of intensity.

Mainstem Abundance Variations. The Poplar mainstem pools (Table 22), like the Middle Fork reach, demonstrated a fairly distinct transverse decrease in ECC towards the deeper study sectors near the center of the stream. But unlike the other sampling sites, station VIP also provided a cross-stream decrease in SCC in spite of the marked elevations in depth. Because of this combination of SCC and ECC declines, total CC also showed a consistent transverse drop at station VIP as a result of the almost complete absence of any inter-association abundance compensations across the river in this one unique case. The intra-segment, midstream declines in the three CC expressions at station VIP were probably caused in various combinations by at least four factors as follows: (1) by the increasing coarseness of the bottom materials towards the middle of the main river pools; (2) by the increasing depths of these midstream sectors; (3) by an enhanced mid-river runoff scouring; and conceivably (4) by the high turbidity levels of the mainstem waters which could restrict light penetration and retard submersant growth in the deeper locales as was outlined earlier. But the small current velocities that were measured during the low flows of the sampling season were probably not an affecting factor in the ponded portions of the upper Poplar River.

The vegetation of the station VI riffles (Table 21) stood in contrast to that of the station's pools by showing a somewhat higher level of inter-association plant abundance compensation across the stream. A vegetative balance of this kind was observed at most of the appraisal sites, and the greater biotic compensation of the VI riffles over the VI pools can be illustrated by the lower standard deviation in total CC that was calculated for the six sectors of the riffle reach (a value of 4.00 which is equivalent to 37% of its mean) in comparison to the standard deviation of the ponded section (a value of 7.24 which is equivalent to 92% of its mean). These mainstem standard deviations when expressed as percentages of the means, however, were higher than the standard deviation percentages that were typically obtained from the total CC levels of the more highly compensated East Fork and Middle Fork segments (e.g., values of 9.53 and 4.32 for stations VP and VII which are equivalent to only 20% and 32% of their means). As a result, highly variable emergent, submersant, and total CC's also became evident among the different station VIR sectors as well as among the site's ponded locations but with the absence of any distinct patterns of transverse change in the fast-water case.

Such cross-stream and non-patterned fluctuations in the CC's of the station VIR sectors were generally correlated with the transverse ups and downs that occurred in the substrate index numbers of the station's sampling locations (Table 13). Thus on an intra-segment basis, and within the strict overall environmental confines that were imposed upon the vegetation of the reach, the substrate coarseness of the individual VIR sectors appeared to be the principal factor that controlled the amounts of plant CC that could become established at any given stream position. Current velocity and water depth probably played comparatively minor intra-segment roles in this regard, and the turbidity-light transmission restrictions of the waters were undoubtedly non-limiting because of the shallow nature of the VIR segment. But on an all-station basis, both substrate and depth were highly effective in retarding the total plant abundance levels of the site. Some adverse all-station effects were also probably derived from runoff scouring, although the low current velocities of station VIR during the inventory season did not appear to be too influential in restricting the station's hydrophytic growth.

Diversity and Biomass Aspects. In addition to possessing an extremely low macrophytic canopy cover percentage, the upper Poplar mainstem also presented a relatively low plant diversity level with the field-recognition of only eight and nine taxa in the riffles and pools respectively along with a tabulation of both the bottom algae group and the floating algae group in each of the station's segments. This small number of taxa in the upper mainstem coincided with the general downstream decline in diversity that developed along the East Poplar-Poplar Rivers, and a near zero diversity was eventually achieved in the lower parts of the main river because of the absence of any underwater vascular plants.

Though observed to be more floristically diverse than the mainstem, the Middle Fork also provided a lower number of taxa than the East Poplar River with a field tabulation of only twelve of the basin's true macrophytes plus the two algal categories. At the name time, both of the mainstem segments and the Middle Fork reach revealed comparatively low to extremely low Taxa/Pt. ratios and secondary line diversities, especially at station VIR, with these same appraisal sites demonstrating low to extremely low ABio readings in association with their reduced canopy cover percentages. These ABio's were somewhat higher in the Middle Fork than in the main river in accord with the Middle Fork's greater abundance levels, but the non-East Fork ABio's were typically much lower than those of the East Fork stations. The distinctively low ABio values that were recorded for the station VI ponded sectors were particularly noteworthy for the inventory.

In the main therefore, the non-East Fork study reaches of the Poplar River basin in Montana contained aquatic plant communities that were nondense and nondescript in character. These communities afforded low floral diversities on a station basis and on a transect point basis, and they had markedly low macrophytic biomass and CC features in correspondence with the generally harsh environments of the Middle Fork and mainstem waters.

Because of the sparse nature of the plant associations at stations VIR, VIP, and VII, the Taxa/Pt. and ABio values that were established for each of the sectors at each of these sites did not typically demonstrate the distinctive cross-stream patterns of change that were spotted for the several East Poplar stations. The only exception to the non-patterned nature of the Taxa/Pt. and ABio variables in the non-East Fork segments was found to reside in the Middle Fork reach where the point diversities tended to decline, as was noted for the East Fork sites, from the diverse and ecotonal NE sector to the more floristically homogeneous middle portions of the stream. But otherwise, the transverse Taxa/Pt. and ABio intersector fluctuations of the non-East Fork stations appeared to be largely haphazard in design, and they were symptomatic of the nonstructured and barely viable aquatic plant communities that happened to inhabit the environmentally borderline mainstem and Middle Fork portions of the drainage.

General Physiognomy. As suggested by the above discussion, the low CC and ABio values of the non-East Fork sites, which paralleled the sites' extremely high TCC/WCC ratios (6.52 at station VIR, 7.79 at station VIP, and 5.35 at station VII), in conjunction with the relatively high bare substrate frequencies, high Bare-Alg. levels, and low Veg. CC percentages of these non-East Fork reaches, point to the presence of a scattered and nondistinctive type of hydrophytic community within each of the mainstem-

Middle Fork inventory segments as described for a section of the station VR waters. The upper main river and midway Middle Fork plant groupings, thereby, were typically comprised of diminutive and scanty underwater plant "springs" and sparse and slight emergent stands that showed a low vertical posture and a low biomass perspective. These inconspicuous macrophytes were scattered across the non-East Fork segments at fairly widespread intervals with a high tabulation of nonvegetated secondary lines and with the bottom algae and floating algae making significant CC contributions to some of the stream locations.

Single taxon tabulations were made at a large fraction of the vegetated non-East Fork transect points in conjunction with the low diversity, abundance, and density levels of the mainstem-Middle Fork sites. However, more than one taxon, which oftentimes involved one of the algal groups, were encountered at about 30% to 60% of the secondary lines that did denote a plant representative, and the exact proportion of these multi-taxa encounters was dependent upon the Taxa/Pt. value of a particular stream position. The macrophytes of these scattered communities tended to be more dense nearer to the banks of the Middle Fork and mainstem waters than in the central parts of the rivers, and a 50% or greater Veg. CC percentage was found closer to the shore because of the fairly consistent presence of emergent vegetation. In an opposing fashion, some of the near midstream sectors, particularly those of the mainstem, were almost devoid of any aquatic plants, and they had extremely low Veg. CC percentages below 50% and approaching 5% because of the less frequent occurrence of any algal and/or macrophytic tabulations.

Of the non-East Fork sites, the Middle Fork afforded the least extreme case of this scattered format of community organization because of its somewhat higher plant abundance levels. But nevertheless, the plant assemblages of both the Middle Fork and the Poplar mainstem did present a markedly different structural picture of aquatic vegetation than the luxurious and plush macrophytic associations of the East Poplar River. However, the floristic discrepancies between the East Fork and non-East Fork reaches were much less pronounced than the structural and organizational differences that were observed to occur in the vegetation of these separate drainage segments.

Floral Characteristics

Mainstem-Middle Fork and East Fork Comparisons. The primary floristic difference between the non-East Fork and East Fork appraisal sites was found to reside in the non-collection of a large number of taxa from the Middle Fork and the upper main river segments that were obtained from the East Poplar stations, and this feature coincides with the comparatively low floral diversities of the non-East Fork waters. Of the twenty-five field-recognized true macrophytic taxa of the study plus the seven macroalgal genera (Tables 3 and 4), 56% were not collected from either of the two mainstem locations, while 41% were not collected from the Middle Fork reach. In contrast, only 3% of these taxa were not retrieved from at least one of the stations along the East Poplar River. Furthermore, although the relatively rare category of taxa within the project's inventory segments demonstrated similarly low canopy cover percentages among all of the sites, the most prevalent of the East Poplar taxa demonstrated much higher CC values than the most prevalent macrophytes of the non-East Fork sampling positions which is in accord with the greater environmental stress and the low total plant abundance levels of the Middle Fork and mainstem sections.

But in spite of the environmental and the plant abundance and diversity differences between the East Poplar and the other drainage waters, the non-East Fork locations, with one exception, did not provide any taxa that went unidentified in the East Poplar River, and almost all of the main river and Middle Fork aquatic plants were recognized at several of the sampling stations along the eastern stream. The green macroalgae Oedogonium represents the single exception in being a unique collection from the Middle Fork of the drainage.

Four of the more abundant taxa at the non-East Fork sites were also observed to be among the dominant forms at some of the East Poplar stations, and this listing includes the following genera: Myriophyllum spicatum, Potamogeton pectinatus, Carex, and Eleocharis. But on the other hand, Hippuris vulgaris along with one or both of the algal groups were observed to be relatively conspicuous plants at some or all the non-East Fork sites, although these same hydrophytes were classified as unimportant floral components of most of the East Poplar segments.

Conversely, two of the prominent East Poplar macrophytes (i.e., Scirpus and Characeae) were classified as rare taxa at the non-East Fork stations, while three of the East Fork dominants were never collected from the Middle Fork-mainstem locations (i.e., Typha latitolia, Sagittaria cuneata, and P. richardsonii). In addition, five of the remaining taxa (i.e., P. filiformis, P. foliosus, Juncus, Zanichella palustris, and Poaceae) were observed to be non-abundant macrophytes throughout the entire study area and at all of the East Fork and non-East Fork sites, and a large number of the minor East Poplar forms (ten taxa) were never collected from the main river and the Middle Fork sampling stations (e.g., Equisetum, Heteranthera dubia, P. robbinsii, Sparganium, and Mentha arvensis). Thus, the absences of certain of the taxa from the non-East Fork sites plus the comparatively low abundances of the more prominent plants that did occur at these locations, coupled with the unique mixtures of the dominant aquatics that were collected from the non-East Fork stations, served to floristically separate to some extent the Middle Fork and the mainstem segments from the East Poplar waters.

Dominant Taxa. Of the twelve true macrophytic taxa and the two algal groups that were tabulated at the three non-East Fork sites, M. spicatum was observed to be among the four most abundant plants at each of the three locations. This prevalence, when paired with the markedly high CC's and the dominance of M. spicatum all along the East Poplar River, points to the supra-dominance of this one submersant species throughout the north-central and northeastern parts of the Poplar River drainage in Montana.

In addition to M. spicatum, one or both of the algal categories were also listed among the dominants at each of the non-East Fork stations, although in contrast to the milfoils, the non-charophytic algae were found to be a comparatively rare floral element along a major stretch of the East Poplar River. These nonvascular plants, therefore, made a much more important contribution to the aquatic vegetation of the Middle Fork and mainstem reaches, comprising between 12% and 34% of these sites total CC's, than they did to the upper and middle East Fork communities where they contributed to less than 4% of the East Poplar's total CC levels.

The greater relative contribution of the non-charophytic algae to the non-East Fork vegetation than to the East Poplar's assemblages was in a small part due to the slight 1.7-fold average enhancement of algal abundance in the Middle Fork and mainstem segments in relation to the lower algal CC's of the upper and middle East Poplar locations. However, this enhanced algal prominence in the non-East Fork reaches was primarily related to the pronounced 3.5- to 12.9-fold drop in the CC's of the true macrophytes from the East Poplar into the main river and across to the East Fork's sister stream. In terms of a proportional canopy cover contribution therefore, the non-charophytic macroalgae were seen as fairly important members of the plant communities at stations VIR, VIP, and VII while being inconspicuous entities of the eastern fork's associations. One exception was found in the extreme lower reach of the East Poplar River where the non-charophytes again comprised a comparatively high percentage (12% to 22%) of the total WCC level of an inventory reach (stations VR and VP). In general, the macroalgae, excluding the Characeae, became significant community members in those stream reaches having the harsher physical conditions, and this observation can be probably extended to the microalgal species such as the diatoms.

Along with M. spicatum and the two algal groups, the four most abundant and dominant macrophytes at each of the non-East Fork stations, ranked in the order of their station WCC values, can be listed as follows: mainstem station VI riffle--H. vulgaris, M. spicatum, bottom algae, and floating algae; mainstem station VI pool--M. spicatum, floating algae, Carex, and Eleocharis; Middle Fork station VII--M. spicatum, Carex, P. pectinatus, and floating algae. As was noted earlier for station VR, this dominant classification of plants in the case of all of the low abundance sites was most commonly descriptive of a much lower CC level than what was calculated for the dominants along the vegetatively distinct East Poplar River. And because of their low taxon CC's, the non-East Fork segments did not provide for an obvious subdominant category of taxa as was delineated for the eastern stream, although Z. palustris and P. foliosus were observed to be somewhat abundant at stations VIR and VII respectively.

Middle Fork and Mainstem Comparisons and Taxa Eliminations. The dominant plant listings of the Middle Fork and the main Poplar River that are presented above, in comparison to such listings that were developed for the different East Poplar stations, act to floristically separate the non-East Fork sites from each of the segments that were evaluated along the eastern fork of the drainage. In a similar fashion, these non-East Fork dominant taxa listings function to separate the Middle Fork and the two mainstem appraisal sites from one another on a floral basis. But beyond these obvious inter-site abundance differences within each of the taxa, the non-East Fork reaches were quite similar in terms of their aquatic flora by basically having the same assortment of plants. That is, stations VIR and VIP afforded nearly identical sets of ten to eleven higher plant taxa except for the absence of Eleocharis from the riffle section. Furthermore, the Middle Fork and the main river segments also provided closely similar sets of thirteen to twenty macrophytic and algal taxa except for the absence of P. foliosus, Juncus, Chara, Nitella, Mougeotia, Oedogonium, and Tribonema from the Poplar mainstem but with the tabulation of these seven genera in the middle stream of the drainage.

The plants that were observed to inhabit the non-East Fork reaches must have been representative of those forms that were able to tolerate and withstand, at least to some degree, the comparatively severe physical conditions that were presented by the Middle Fork and the upper Poplar River drainage courses. But some levels of stress did become evident in these tolerant macrophytes as described by their generally low CC levels at the non-East Fork sites. A large number of the basin's more susceptible taxa (approaching fourteen representatives), in turn, were eliminated from the aquatic flora when moving from the East Poplar into the upper Poplar mainstem as a result of the harsher environmental conditions that were imposed by the latter stream.

By the same token, a fair number of the taxa (around eight representatives) were "weeded out" by the increased severity of the physical factors when moving from the East Fork across to Middle Fork portion of the Poplar basin, and seven of the less tolerant hydrophytes were eliminated when travelling from the Middle Fork into the upper mainstem waters. In addition, several of the macrophytes (in the vicinity of nine taxa) dropped-out when moving from the upper East Poplar into its lowest reach in association with the somewhat harsher environs that occurred near the mouth of the river, and such floral eliminations became even much more distinct when viewing the lower parts of the main Poplar River because of the absence of any underwater vascular plants. Extremely wide-ranging aquatic macrophyte communities were therefore examined in the Poplar basin study area in relation to the variations that were observed in their floral compositions, in their total and taxon abundance levels, and in their structural and organizational features, and these botanical differences were closely tied to the changes that were seen in the physical characteristics of the nine separate appraisal sites.

APPENDED DISCUSSION

REFERENCES TO OTHER PROJECTS

Intra-Basin Investigations

The floral information that was secured from the Biological Resources Committee (Tennant and Loch, 1979) reconnaissance of the upper East Poplar River in Montana has been incorporated into the discussions and tables of this report, as have the general findings from several of the Canadian studies that were conducted in the Saskatchewan portion of the drainage (e.g., Baron, 1974; Cullimore, 1975 and 1976). As a further evaluation, the Montana Department of Fish, Wildlife, and Parks (MDFWP) obtained infrared aerial photographs of four sections of the East Poplar between the international boundary and the river's mouth near Scobey, Montana, and one stream section was photographed by this agency on the upper Poplar mainstem (DeSimone, 1980). The MDFWP work was conducted in order to obtain some insights into the amount of stream bottom that was covered by emergent vegetation since this feature is important for judging the quality of habitat for waterfowl and other animals. For the East Poplar, the percentages of emergently covered streambed at the four MDFWP locations ranged from 5.8% to 40.0% with a river average of 19.6%, while the upper main river location produced a much lower out-of-water percentage that was only equal to 2.3%.

The results from the MDFWP photographic study can be compared to the vegetative data that were obtained from this more extensive, field-based macrophyte inventory through the use of the true canopy cover (TCC) percentages that were calculated for the emergent plants at each of the appraisal sites. For this project and the East Poplar River, these emergent TCC percentages ranged from 20.8% to 74.2% with a mean of 59.4% for the six East Fork stations. The upper Poplar mainstem and the Middle Fork segments produced lower out-of-water TCC figures between 13% and 23%.

The emergent percentages of this transect project were found to be much higher than those from the MDFWP evaluations for the comparable streams, but the design of this on-site field investigation enabled a tabulation of the sparse and diminutive out-of-water forms such as Carex, Eleocharis, Hippuris, and Poaceae which could not be readily picked up via a photographic approach. As suggested by DeSimone (1980), the aerial photographs would primarily pinpoint only the dense bulrush and cat-tail stands plus a few of the other kinds of more obvious emergent morphologies while excluding many of the less robust taxa. Thus, if only the TCC values of the four most conspicuous out-of-water macrophytes of the survey are assessed with their distinct vertical and aeral postures (i.e., Scirpus, Typha, Sagittaria, and Sparganium), then the East Poplar's adjusted emergent percentages from the transect assessments ranged from about 1% to 53% with a river average of 20.4%. This corrected mean is now closely comparable to the 19.6% average that was established by DeSimone for the same stream.

In a similar fashion, an adjusted emergent TCC of 1.2% was calculated for the upper main river reach (with a 1.7% figure for the Middle Fork), and this mainstem percentage is also not too far removed from the MDFWP value of 2.3%. The close similarity of these out-of-water canopy cover numbers from the two projects is somewhat surprising given the marked disparity of their separate methodologies, and this comparability tends to confirm the reliability of the vegetative data that were collected from the Poplar drainage using the transect line applications.

Extra-Basin Investigations

Comparable Projects. The abundance features of the aquatic macrophytes in the Poplar drainage streams as described by the results from this transect line inventory can also be referenced to the CC's that were obtained from other lotic systems in the case that the same methodologies were used in developing the CC values. Such inter-basin comparisons will then afford an added perspective with respect to evaluating the nature of the aquatic plant communities that were found to reside in the Poplar waters. The results from two vegetative studies that happened to use the transect line approach, i.e., the line intercept method as originally developed by Canfield (1942), in an area outside of the Poplar region can be applied to these comparisons by using the true CC expressions that were calculated from the Poplar data instead of the WCC renditions. These TCC percentages are summarized in Tables 15 to 23 of this report along with the WCC values.

One of the non-Poplar studies (Horpestad, 1969) was completed on the Madison River, on the lower Gibbon River, and on an extremely lower part of the Firehole River in Yellowstone National Park. These stream reaches are found in the same geographic area and are within the vicinity of fifteen miles from the Montana-Wyoming border where the Firehole and Gibbon Rivers join to form the Madison. The second non-Poplar investigation with comparable data (Rasmussen, 1968) was also completed in the Park's Madison drainage, and it involved a phytosociological evaluation of a fairly long stretch of the Firehole tributary.

The vegetative comparisons of these rivers to the Poplar streams are especially useful since the upper and middle reaches of the Madison have been described as noteworthy from a botanical standpoint because of the presence of plush and distinctive aquatic macrophyte growths within their waters. But for contrast, the plant communities in the Gibbon River, in the upper and middle Firehole River, and in the lower Madison segment inside of the Park are much less pronounced than those of the upper and middle mainstem sections. Many of the hydrophytic taxa that were spotted in the Poplar basin have also been identified via these Madison drainage studies (e.g., Characeae, Eleocharis acicularis, Hippuris vulgaris, Myriophyllum spicatum var. exalbescens, Potamogeton pectinatus, and Zanichella palustris), although numerous floristic differences do become evident between the two lotic systems. Such floral discrepancies might be expected, however, since the two study regions are located about 400 miles apart and are situated in markedly different scenic settings; the Madison is located in a mountainous area, while the Poplar is found on the northern Great Plains.

Data Summaries. Horpestad (1969) obtained the following canopy cover percentages from eight stations along the Madison River: values between 122% and 222% for an upper reach (three sites) with its luxurious macrophyte associations, values of 37.0% and 43.1% for the lower Park segment (two sites) with its less pronounced plant developments, and somewhat high but intermediate CC's ranging between 75% and 120% for a middle river section (three sites). An average CC of 117% was calculated for these eight Madison locations.

Rasmussen (1968), after assessing twelve stations, found true CC to vary from 18% to 35% for three of the four upper Firehole River sites, although a distinctly low rating of only 1.7% was secured the most upstream location. Canopy covers that also ranged between 18% and 35% were taken from a middle Firehole reach (four sites), while higher CC's between 47% and 67% were measured by Rasmussen for the four sites on the more vegetatively established lower portions of the tributary stream. An average CC of 33.5% was calculated for these twelve Firehole stations. Horpestad (1969), in turn, obtained widely disparate CC's of 11.6% and 134.1% for two lower positions on the Firehole that were placed just above the stream's Madison confluence, and a CC percentage of 57.4% was measured at a single location on the lower Gibbon River.

The non-Poplar CC numbers listed above refer only to the higher vascular plants plus the charophytes since the macroalgae were not tabulated in the two Madison drainage evaluations. The Poplar data, therefore, have to be adjusted before legitimate vegetational comparisons can be initiated between the Madison and Poplar studies. This correction can be made by simply subtracting the true CC percentages of the floating algae and the bottom algae at a Poplar site from the station total for this parameter.

After making the necessary adjustments for the macroalgae, the corrected true CC's of the East Poplar River were observed to range from 106% to 184% for the river's upstream ponded reach near the international border with its marked macrophytic growths (stations I to III) to generally lower values of 123.8% and 76.5% for the ponded and riffle segments near the stream's mouth (stations VP and VR) with its more severe environmental conditions. A middle station (IV) on the East Poplar produced an adjusted true CC of 157.0%, and an average of 133.4% was determined for the six East Poplar sites. The upper Poplar River mainstem demonstrated comparatively reduced algae-corrected CC's of 46.1% and 50.8% for the ponded and riffle sections (stations VIP and VIR), while a value of 65.3% was obtained from the ponded stretch that was evaluated at the midway Middle Fork location (station VII) in the Poplar basin.

Inter-Study Comparisons. In terms of comparing the true macrophytic abundance levels (sans the non-charophytic algae) of the Poplar and Madison systems, the absolute TCC values and the range of TCC's that were obtained through the relatively short geographic distances of the Poplar inventory were generally equivalent to the TCC numbers and variations that were measured for the Madison streams through a similarly narrow geographic span. But the Madison drainage in Yellowstone National Park tended to show a somewhat lower CC percentage for several of its more vegetatively barren reaches (e.g., the upper and middle Firehole) than the CC's that were obtained from the low plant abundance segments of the upper Poplar basin. Such a discrepancy points to the likelihood of a lusher overall aquatic vegetation in the Poplar River study area relative to what was described for a large part of the Madison survey region. This observation is reflected in the lower CC means of the Madison and Firehole rivers relative to the CC mean of the East Poplar, and it is also reflected by the lower all-station CC average of the two Madison studies (66.9% for the twenty-three combined sampling locations) versus the all-station average of the Poplar investigation (107.0% for the nine appraisal sites).

However, the lower Poplar mainstem and the Poplar West Fork with their lack of underwater hydrophytes deviated from this inter-basin canopy cover relationship by providing lower plant abundance levels than most of the Madison drainage streams. As a result, the general physiognomy of the Poplar plant communities that were located outside of the main study area were probably most similar to the depauperate association that was assessed by Rasmussen (1969) in the extreme upper Firehole segment.

With respect to a more specific inter-basin comparison, the upper and middle parts of the East Poplar River (stations I to IV) and the upper reach of the Madison River demonstrated generally similar true CC percentages for the vascular plants plus the charophytes, although the upper Madison did afford a slightly higher abundance level than the upper-middle East Poplar with a Madison average of 182% versus an East Poplar average of 150%. Nevertheless, a relatively close correspondence can be seen between the CC data of the two separate stream reaches, and this feature in association with the description and documentation of a luxurious macrophyte assemblage in the upper Madison acts to further illustrate the pronounced and distinctive nature of the plant communities that were uncovered in the upper and middle segments of the East Poplar River. But in the case of both the Madison and Poplar drainage waters, hydrophytic CC values were observed to markedly drop in those stream reaches where the environmental conditions became less amenable to extensive macrophyte growths, and comparatively low CC's, as well as comparatively high CC's, were obtained from some of the river sections in both of the regions.

As one example of these intra-drainage abundance changes, CC's were seen to drop by 78% from the upper Madison in Yellowstone Park to a mean value of 43% for the Park's lower Madison section (Horpestad, 1969). For comparison, CC's declined by 68% from the upper East Poplar to a downstream mean of 48% in the upper Poplar River mainstem. The close comparabilities of this kind that were identified between the separate vegetative studies of the two drainage areas, thereby, serve to additionally validate the types of numbers and the types of data variations that were acquired from the transect line field work in the Poplar basin.

PHENOLOGY

In addition to recording the occurrence of one or more of the aquatic macrophyte taxa at each of the secondary lines along a Poplar station's transect crossings (or the non-occurrence of any plants), the presence or absence of flowering-fruiting structures on each of the tabulated vascular macrophytes was also noted for each of the transect points. This accessory reproductive information has not been included into the main vegetative data tables of the report (Tables 15 to 23), but it has been summarized in Table 24 which lists the percentage of the weighted canopy cover of each of the stations' taxa that presented reproductive parts. The dashed lines in the table columns denote the non-collection of a taxa from an appraisal site, and the station percentages across all of the taxa and taxa percentages across all of the stations have also been included.

As suggested by Table 24, eleven of the field-recognized taxa in the Poplar River drainage of Montana demonstrated flower-fruiting structures during this study at varying levels of frequency, and this listing includes several of the more prevalent basin taxa as well as some of the region's less common forms. Four of the abundant vascular aquatics (Scirpus, Typha latifolia, Sagittaria cuneata, and Potamogeton richardsonii) and three of the relatively inconspicuous taxa (Mentha arvensis, Heteranthera dubia, and Sparganium) provided a high frequency of reproductive counts among their field tabulations, while two of the dominants (Myriophyllum spicatum and P. pectinatus) and two of the scarcer representatives (Poaceae and P. robbinsii) afforded a low talley of flower-bearing and/or fruit-bearing plants. Of course, a large number of the basin's rare taxa (e.g., P. foliosus, Zanichella palustris, and Hippuris vulgaris) and a few of the more dominant macrophytes (e.g., Carex and Eleocharis) were never encountered in the sexually reproducing stage of their life cycles when making the Poplar site visitations.

The emergent macrophytes which have been situated towards the top of the Table 24 taxa array typically demonstrated a more frequent occurrence of reproductive parts than the underwater plants that were located nearer to the bottom of the series so that the stations showing the highest percentages of sexually reproducing forms (stations I, II, and IV) were those sites which provided the higher out-of-water CC levels. Station III, therefore, revealed a relatively low frequency of flowering-fruiting tabulations because of its reduced emergent CC's (Table 17). Furthermore, those stream

Table 24. Percentage of aquatic macrophyte canopy cover in the Poplar River drainage demonstrating flowering-fruiting structures by taxa and by appraisal site.

	by Station									by Study
Taxa	I	II	III	IV	VR	VP	VIR	VIP	VII	Area
Mentha	0.0	50.0	--	100.	100.	72.7	--	--	--	71.9
Scirpus	7.3	95.5	--	91.6	74.3	0.0	0.0	0.0	0.0	62.8
Typha	--	77.3	--	50.0	--	--	--	--	--	77.1
Poaceae	0.0	4.1	0.0	0.0	--	0.0	0.0	0.0	0.0	1.0
Sagittaria	30.4	50.9	0.0	0.0	--	0.0	--	--	--	33.4
Sparganium	14.8	9.6	0.0	32.9		--	--	--	--	15.9
Heteranthera	--	0.0	100.	--	--	--	--	--	--	50.0
Myriophyllum	0.0	9.5	3.7	12.0	0.0	0.0	0.0	0.0	0.0	6.7
Potamogeton										
pectinatus	65.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1
richardsonii	0.0	9.0	45.9	34.9	--	--	--	--	--	39.1
robbinsii	--	0.0	16.7	--	--	--	--	--	--	3.6
Station Percentages*	18.3	28.2	4.8	28.3	1.7	0.2	0.0	0.0	0.0	15.0

*The higher plant taxa that failed to demonstrate reproductive parts during the inventory are not listed, but the overall station percentages were computed after the inclusion of the canopy covers of these vegetative macrophytes into the calculations.

reaches having the harsher environmental conditions with their resultantly retardant plant abundance features afforded a lower frequency of macrophytes that bore reproductive parts than the more environmentally amenable segments. This feature is illustrated by stations VI and VII which had generally severe physical characteristics, and the few vascular plants that were tabulated at these sites were never recorded in a reproductive phase during the inventory. In addition, the downstream-most reach of the East Poplar (station V) also provided a comparatively low percentage of sexually reproducing macrophytes in comparison to stations I to IV in conjunction with the near-mouth segment's somewhat harsher environmental factors and its greatly reduced CC values.

TRIP-TO-TRIP ASSESSMENTS

Purpose and Approach

Three sampling excursions using the same methodologies were conducted in the Poplar River basin to each of the inventory stations (late July and August and mid-September), and the study results that are presented in Tables 15 to 24 were calculated after pooling the data from all of the trips. In addition, emergent, submersant, and total E + S weighted CC percentages plus bare substrate frequencies were separately determined by station and on an all-station basis from each of the trip's data (Table 25) in order to provide the opportunity for making various intra-study data assessments. Such inter-trip

Table 25. Emergent, submersant, and total station canopy cover percentages and bare substrate frequencies obtained on each of the three sampling trips to the Poplar River basin at each of the appraisal sites plus a summary of the inter-trip variations.

Sites	Data Groups#	Weighted Canopy Cover Percentages			Average Inter-Trip Differences	Relative Inter-Trip Differences*
		Trip 1	Trip 2	Trip 3		
I	Emerg.	33.47	26.73	38.38	7.77	18.0
I	Submer.	9.43	12.83	10.68	2.27	5.3
I	Total	42.90	39.56	49.05	6.33	14.7
I	Bare S.	19.68	28.32	18.92	6.27	27.1
II	Emerg.	22.26	33.05	32.25	7.19	9.5
II	Submer.	50.75	47.46	40.08	7.11	9.4
II	Total	73.01	80.51	72.33	5.45	7.2
II	Bare S.	1.08	0.85	5.00	2.77	114.5
III	Emerg.	7.71	5.49	2.89	3.21	5.2
III	Submer.	55.78	57.45	58.03	1.50	2.4
III	Total	63.49	62.94	60.92	1.71	2.7
III	Bare S.	10.84	9.80	9.86	0.69	6.8
IV	Emerg.	25.84	33.57	36.44	7.07	9.9
IV	Submer.	41.36	39.22	37.95	2.27	3.2
IV	Total	67.20	72.79	74.38	4.79	6.7
IV	Bare S.	1.60	4.65	4.11	2.03	58.0
VR	Emerg.	7.23	6.25	--	0.98	4.7
VR	Submer.	17.11	5.31	--	11.80	56.8
VR	Total	24.34	11.56	--	12.78	61.5
VR	Bare S.	26.51	46.88	--	20.37	63.3
VP	Emerg.	11.01	10.00	12.86	1.91	4.1
VP	Submer.	41.19	19.90	41.17	14.19	30.4
VP	Total	52.20	29.90	54.03	16.09	34.4
VP	Bare S.	10.09	31.37	24.68	14.19	63.9
VIR	Emerg.	0.67	--	2.23	1.56	14.2
VIR	Submer.	8.67	--	9.70	1.03	9.3
VIR	Total	9.33	--	11.93	2.60	23.6
VIR	Bare S.	37.78	--	46.99	9.21	21.1
VIP	Emerg.	1.69	4.51	1.20	2.21	29.5
VIP	Submer.	6.85	4.02	4.38	1.89	25.2
VIP	Total	8.54	8.53	5.58	1.97	26.3
VIP	Bare S.	60.67	67.65	62.50	4.65	7.3
VII	Emerg.	6.24	2.58	2.30	2.63	19.3
VII	Submer.	11.19	12.97	6.11	4.57	33.5
VII	Total	17.43	15.55	8.41	6.01	44.1
VII	Bare S.	40.37	38.28	68.25	19.98	40.5
SA	Emerg.	16.21	15.65	15.31	0.60	1.4
SA	Submer.	26.34	25.66	28.35	1.79	4.2
SA	Total	42.55	41.31	43.66	1.56	3.7
SA	Bare S.	21.31	27.19	28.45	4.76	18.5

#Emerg.--emergent plant association; Submer.--submersant association; Total--emergent plus submersant (entire community); Bare S.--bare substrate; SA--study area (i.e., all of the sites).

*The relative difference values were calculated by dividing the average difference numbers by the all-trip total canopy cover percentages or the bare substrate frequencies of the stations, or the study area, as appropriate.

comparisons were intended as a means for assessing the variability of the CC numbers that were obtained from the survey, for establishing the extent of the study's experimental error, for determining the occurrence of any seasonal trends, and for checking the consistency of the inventory approach.

A high CC variation among the data sets of the trips would indicate that a large experimental error component has been incorporated into the investigation, and this occurrence would tend to downgrade the accuracy and precision of the sampling effort. However, a low inter-trip CC variation would point to a low experimental error, and it would act to confirm the reliability of the inventory numbers. The general validity of this transect line project in the Poplar drainage in the sense of accurately describing what was actually there botanically has been generally confirmed by the close comparisons that were noted between the vegetative results of the Poplar field work and the results that were obtained from the three other intra-basin and extra-basin evaluations (Rasmussen, 1968; Horpestad, 1969; and DeSimone, 1980).

Experimental Error

Magnitudes. The small average absolute CC discrepancies, the small average absolute substrate frequency difference, and the small relative mean differences in CC (Table 25) that were obtained among the three sampling trips across all of the appraisal sites (the SA numbers) indicate that a relatively minor experimental error component has been built into the Poplar basin's synecological data base when the entire study area is considered. This observation points to a consistent application through each of the project's field forays of the modified line intercept method that was chosen to secure the vegetative data of the inventory. An inconsistent use of this method from one data gathering excursion to another could have significantly contributed to the production of a high experimental error, but this does not appear to be the case for the Poplar work.

As indicated in Table 25, the substrate variable demonstrated much higher inter-trip SA differences on an absolute basis and on a relative basis than the CC parameters. However, these relative numbers were accentuated to some extent in the substrate case over the CC descriptions because of the lower bare substrate means. Also, the bare substrate evaluations appeared to be just naturally more variable among the trips than the canopy cover expressions. A part of this enhanced variation could have been due to the occurrence of a subtle seasonal change in the Poplar's plant communities, and this type of alteration seems to have involved a slight increase in the bare substrate frequencies of the sites with a loss of some of the associations' vegetative canopy cover when going from the summer to the fall months. Such seasonal aspects will be discussed in more detail later. As a related observation, the submersant plant group provided a greater CC variability among the three trips than the emergent forms.

The absolute inter-trip differences in the Poplar's canopy covers and in the region's bare substrate frequencies were also seen to be quite small for the project on a station basis. These values were always less than 21%, and 86% of the differences were observed to be less than 14% with 67% less than 7% and 44% less than 3%. Nonetheless, fairly high relative differences were calculated for several of the reaches, although in many of these instances, a low absolute discrepancy was involved that was accentuated on a relative scale because of its reference to the site's low CC or bare substrate means (e.g., the substrate variable at stations II and IV and the CC expressions at station VI). But high absolute and high relative differences were obtained in tandem from a few of the inventory segments and plant associations, and this combination is suggestive of the development of some significant data variations among the field trips at a set of specific drainage locations. The major examples of this occurrence were found with the emergent association and the bare substrates at station I and with the submersant associations and the bare substrates at stations VR, VP, and VII.

Sources. In accord with conclusion that was derived from the SA comparisons in Table 25, the occasional development of a somewhat high inter-trip CC variation at certain of the specific Poplar sites again did not appear to be caused by any alterations among the trips in the application of the transect methodologies of the project. Thus judgment is based on the fact that a high CC difference in one of the associations, and carried into the total CC parameter, was typically accompanied by a low difference in the other plant group, whereas a methods-related error would have become consistently evident through all of a station's data. Furthermore, an unexpectedly low CC tabulation on one of the trips to a stream location was commonly paralleled, as might be anticipated, by the measurement of a high bare substrate frequency at that station on the same field excursion.

In light of the above observations, the inter-trip variations of the inventory seem to be primarily related to a natural component of the experimental error expression where the stream vegetation inherently changed along a length of the reach that was being evaluated. These natural vegetational changes would then be reflected in the procurement of somewhat variable CC's from the different trips to an appraisal site as a result of the separate sets of adjacent transect lines that were examined along the inventory segment on each of the station visitations. Such natural variations would then tend to be accentuated on a relative scale at those sites having the lower plant abundance characteristics (e.g., station VI on the mainstem).

The degree of the inter-transect canopy cover variations of a synecological study, as derived from the natural vegetational alterations that occur along the length of a stream, are at least a partial function of the distances that are used to separate the individual transect lines. This type of experimental error, therefore, which was the most important source in the Poplar River basin inventory, can be progressively reduced by evaluating sets of more closely spaced transect crossings. But although this adjustment will probably reduce the variation of a project's data base, the end result would be the vegetative description of a smaller lotic segment. This more restrictive application then could also bias the plant community picture of a stream by providing a narrow focus at the expense of obtaining a broad overview of the total macrophyte assemblage that might happen to inhabit a somewhat longer expanse of the reach that is to be surveyed.

In essence, some amount of experimental variation as a result of the natural upstream-downstream vegetational changes of a lotic system cannot be entirely avoided, and the goal is to reduce this source of variability to some acceptable level while still being able to adequately describe a representative and overall piece of the vegetation in the stream reach that is under consideration. Thus, the inter-transect distances that were utilized in the Poplar investigation were selected in the hope of securing an equitable balance between these two opposing aspects: a broad and reasonably accurate botanical description of a suitably and representatively long inventory segment at each of the sites with the retention of an acceptable level of experimental error.

The small inter-trip SA differences in Table 25, plus the generally low inter-trip CC differences that were obtained across the fairly extensive 100-foot to 900-foot segments that were surveyed at the separate study stations, suggest that this goal has been largely achieved by the Poplar effort. In addition, the methods-related and the seasonally-related sources of potential experimental error probably made only minor contributions to the trip-to-trip data variations of the investigation, and all of these features indicate that the field work might be successfully repeated by using the same transect methodologies and the same sampling program at some future date. These subsequent evaluations will then lead to the production of reliable and valid follow-up plant data that will be available for comparative use in relation to this baseline survey for judging the development of any Cookson impoundment-based vegetational changes that could conceivably occur along the East Poplar River and the Poplar mainstem through the next several years.

Seasonal Variations

Types of Potential Change. Natural seasonal declines in the canopy cover levels of the Poplar aquatic macrophyte communities might be expected to occur from the warm weather and high growth seasons of spring and summer to the cold weather months of fall and winter when the plants begin to undergo senescence and eventually dieback to their dormant overwintering organs. In addition, a drop in the occurrence of sexually reproducing plants might also be anticipated when moving into the fall months. Some decreases of this kind, therefore, could become evident among the CC data that were obtained from the three separate field excursions to the Poplar region since these trips were made through a 1.5-month seasonal span from midsummer to early autumn.

The development of this type of inter-trip difference would make a contribution to the experimental error component of the project, and the occurrence of such seasonally-related drops in the study area's CC numbers and its reproducing plant tabulations should be readily identifiable and confirmed by the observation of a consistent pattern of decrease in these macrophytic measurements from the first field trip to the second trip and into the final field outing. If such distinctive patterns do happen to emerge, then a large part of the experimental error might be attributed to the natural progression of seasonal change. But contrariwise, the nonrecognition of a regular pattern of decline among the trips' CC data would point either to a general absence of any seasonal drops in streams' plant abundance levels through the period of sampling, i.e., the field work was terminated before any pronounced losses in plant biomass could happen to occur, or to very minor variations that could not be picked up in the face of the system's normal background fluctuations. In both of these latter cases, the inter-trip CC discrepancies of the inventory would be primarily related to other causes instead of any seasonal effects, and such a nonseasonal listing would include the natural longitudinal alterations in vegetation that are commonly seen along a stream reach.

Magnitudes of Change. As indicated by the SA values in Table 25, the all-station CC of the submersant association and the E + S expression of all of the sites did not demonstrate a consistent pattern of change across the three field trips, and this same characteristic was also recognized with reference to most of the individual inventory segments. Furthermore, although the SA CC's of the emergent association did demonstrate a continuous but small 5.5% decline from trip one to trip three, such CC drops were not particularly distinctive at many of the individual sites. In the main therefore, the seasonally-related, trip-to-trip abundance changes in the plant communities of the Poplar drainage, as they occurred within the framework of the project's sampling program, were found to be nonexistent or quite minor in nature, and the evidence of an actual seasonal influence was most clearly revealed in the form of the broader and more general study variables such as bare substrate frequency rather than in the form of the more complex parameters such as the weighted CC expression. Thus, the CC variations of the study that might have been related to the normal month-to-month progressions of the drainage were observed to make only negligible contributions to the overall experimental error partition of the project's data base.

The most obvious trends of seasonal change that emerged from the study data were identified in the following parameters: in the bare substrate frequencies (Bare Sub.), in the inversely related Veg. CC variable (defined as 100% minus Bare Sub.), in the true CC expression, and in the rate that the plant tabulations presented a flowering-fruiting structure. The bare substrate percentages, with an overall value of 25.7%, demonstrated a consistent increase from the first to the third sampling trip on a study area basis (Table 25) with a small and concommitant 9% drop in the Veg.CC numbers, and these same patterns of change also became evident at a large proportion of the individual appraisal sites. Similarly, true CC tended to decline by a small degree (by about 10%) from the end of July to the middle of September as did the frequency at which sexually reproducing plants were counted in the inventory region. The latter sequence can be described as follows: trip one--8.2% of the basin's WCC, trip two--6.4%, and trip three--5.8% with an all-trip and all-station value of 6.8%.

The seasonal variations that are described above might be expected for the Poplar's macrophyte communities in relation to the normal life cycles of the communities' aquatic plants, although the autumnal decreases in the true CC percentages and the declines in the frequency of the reproducing forms could not be shown to be totally consistent for all of the stations or for all of the plant groups and their associated taxa. Furthermore, the identified trip-to-trip differences along these lines were quite small so that the seasonal factors had a largely insignificant influence on the study results, and such seasonal effects should pose no problems for successfully repeating the inventory at some future time. The bulk of the cold weather changes that would be predicted for the Poplar's plant associations must have occurred during a period that followed the date of the last field foray to the study area.

PLANT ABUNDANCE AND WATER QUALITY PARAMETER CONSIDERATIONS

Stream Production

As described previously, certain stream reaches in the Poplar River basin were suggestive of high photosynthetic activities and high plant biomass levels because of the segments high pH values, high dissolved oxygen concentrations, and high percent saturations (Table 8). The seasonal drops in pH and dissolved oxygen (DO) that occurred in the drainage toward the autumn months were in turn indicative of decreasing photosynthetic rates which could have been caused by a seasonal reduction in the submersant biomass levels of the rivers from the first to the last field trip. However, the CC data of the inventory suggest that the extremely small macrophytic abundance losses that might have occurred towards the early fall season of the inventory period were of an inadequate magnitude to account for a very large proportion of the projected photosynthetic declines. Some other affecting factors, thereby, must have been primarily operable in instituting the seasonal drops in the production levels of the streams and the summer to fall declines in the pH and DO characteristics of the basin's water samples.

The pronounced summer to fall decreases in the temperature of the rivers (Table 9) coupled with the autumnal onset of plant senescence appeared to be the prime candidates for causing these seasonal adjustments in the streams physiological and water quality characteristics since both of these factors are important for establishing the amount of photosynthetic activity. But in contrast to these seasonal alterations, the longitudinal variations that were observed in the pH and DO measurements taken along the East Poplar River and into the upper Poplar mainstem, which were produced by an upstream-downstream change in the production capacities of the streams' aquatic macrophyte assemblages, were probably caused by a longitudinal alteration in the plant abundance levels of the different stream reaches.

The general correspondence between plant abundance and water quality in the study region is generally illustrated by the correlations that were spotted between the pH-DO values and the SCC percentages of the different stream sections, and these relationships can be summarized as follows: High pH-DO levels were typically obtained in conjunction with the higher CC readings of a reach (stations III and IV), and general drops in pH-DO and in SCC were noted when moving into the lower East Poplar with a further drop in these same variables identified for the Poplar mainstem. In addition, relatively low pH-DO concentrations were obtained at station I in accord with the comparatively low SCC's of this border location, and lower pH-DO values were obtained in the upper main river than in the Middle Fork in accord with the Middle Fork's somewhat greater density of underwater plants. Thus, the Poplar inventory did demonstrate some definite agreements between its water quality and plant abundance data with these parallels serving to additionally validate the vegetative aspects of the project. Nevertheless, a few obvious inconsistencies between the CC and the pH-DO numbers did become evident in the study results, and these discrepancies have been briefly outlined in an earlier section of this report.

Affecting Factors

The potential influences of the turbidity-suspended sediment-light transmission triumverate for retarding aquatic plant photosynthesis and macrophyte development at a few of the stream sectors in the Poplar River drainage have been discussed previously. But the suspended sediment concentrations and the current velocity-bedload movements of the streams during the summer and early fall sampling seasons were probably not distinctive enough to produce any significant direct effects of an adverse nature on the macrophytic communities in the sense of smothering or scouring the plants, although the bedload factor could be an important consideration in this regard at some of the sites during the runoff periods; i.e., at those locations that are further removed from the Cookson impoundment. The summer-fall levels of pH and DO in the different Poplar waters were largely established by the extent of the biota's metabolic activity, and these water quality parameters were never at appropriate levels to adversely and reversely influence the basin's hydrophytes. However, pH and DO could be adequately high (pH in the summer) or sufficiently low (DO in the winter) during certain seasons of the year to conceivably affect other members of the Poplar's underwater biota to some negative degree.

In addition, the salinity and the temperature variations among the sampling stations did not appear to be of a suitable size to differentially effect the plant growths that could undergo ecesis at one site with reference to those that could become established at a different stream position. But temperature did have some marked seasonal influences in all of the reaches as was noted above. In contrast, salinity was not descriptive of a seasonally variable environmental factor with reference to impacting the aquatic flora, and the salinity changes of the Poplar drainage are of most concern biologically from a time perspective where future salinity enhancements related to the Cookson Reservoir could potentially affect the basin's macrophytes and its other forms of aquatic life in a negative fashion at some future date. The plush aquatic plant communities that were examined along the East Poplar River indicate that the pre-impoundment salinity concentrations of the drainage were of an insufficient magnitude to have any appreciable effects on the streams' vegetation.

POSTSCRIPT

STUDY SYNOPSIS

One of the major objectives of the aquatic plant inventory in the Poplar River basin of Montana was to secure baseline vegetative data along with the conjoining physical and water quality details of the region as a response to the Cookson impoundment on the East Poplar River. This type of information will then be available for future comparative purposes in the case that the survey effort can be repeated at a later date in the same study area by using an identical transect methodology and a closely similar sampling program. Data comparisons between this early 1980's background inventory and any subsequent follow-up work will then provide the basis for making judgements on whether the Cookson Reservoir near Coronach, Saskatchewan might have had an influence on the lotic macrophyte communities of the drainage and an adverse effect on the hydrobiological habitat values of the Poplar system.

The background vegetative, physical, and water quality numbers that will be needed to make these time-related comparisons have been included into the several data tables of this present report. The report also describes in some detail the field methods, appraisal sites, sampling frequencies, and laboratory applications that were utilized in this initial investigation, and it discusses the means of data reduction, refinement, and manipulation that were employed to develop the tabulated figures so that the study format might be closely copied at some future date in order to ensure the obtainment of valid inter-survey comparisons. In addition, the taxonomic restrictions, experimental error features, and the various difficulties that were uncovered while completing this baseline botanical project have been discussed in this write-up as a preface to any subsequent survey activities that might be directed to the macrophytic plants of the Poplar River area.

With the announcement of the coal-fired electrical generation development near the town of Coronach in Canada, which involved the construction of Morrison Dam, numerous biological, water quality, and hydrological investigations and assessments were undertaken in the Poplar River basin on both sides of the United States-Canadian border. But in spite of these many activities, very little information became available concerning the macrophytic communities of the Poplar drainage streams in Montana. This void then points to another basic objective of the inventory work which was to generally describe and characterize these plant assemblages at several suitable and appropriate locations within the region, and this objective has been largely fulfilled through the discussions and presentations of this particular report.

As an accessory avenue, the tabular data that have been summarized in this write-up are readily amenable to a statistical analysis of the various impacts that the different physical and water quality factors of the streams might have on the abundance, diversity, distributional, and floristic attributes of the Poplar's plant communities and taxa. However, these kinds of complex and quantitative assessments were deemed to be beyond the scope of this report, although efforts along these lines could be undertaken at a later time as a means of more definitely delineating the potential influence that the Cookson impoundment might have on the hydrophytes of the Poplar waters below the Morrison Dam outfall. But some preliminary analyses that deal with the physical and water quality relationships of the macrophytes have been presented in this initial document, and these precursory assessments allow for a first-stage evaluation of the possible vegetational effects of the East Poplar impoundment on the river's plant communities. This inaugural discussion is presented in the final chapter of this report.

POSSIBLE IMPOUNDMENT EFFECTS

Descriptive Aspects

Overview. Several morphometric changes have been predicted for the East Poplar River of Montana as a result of the Canadian power development and the formation of the Cookson Reservoir, and these physical alterations are expected to have a variety of repercussions on the river's macrophyte communities. As summarized by Tennant and Loch (1979), these physical changes can be listed as follows: A 53% to 60% reduction in bank-full width, a 42% to 56% reduction in bank-full depth, a 15% to 21% reduction in current velocity, a definite lowering of stream flow, a marked dampening of the spring freshet plus a correspondingly more rapid warming of the system following the cold weather months, anda reduction in turbidity levels leading to a greater clarity of the water.

All of these physical factors are anticipated to lead to a further entrenchment of the rooted aquatic plants with a minor transfer in algal and macrophytic abundances that should favor the latter forms, and a general increase in hydrophytic biomass is also foreseen for the primary channel of the river. However, with a loss of some of the stream width, an opposing and small proportional decline in aquatic plant abundance that occurs along the banks of the river can be envisioned with a near shore shift to terrestial vegetation as a result of the reduction in the water-covered surface area of the streambed. Such vegetative changes along with the physical and water quality alterations are expected to be accompanied by significant decreases and disruptions in the stream's fishery and in its waterfowl, shorebird, and macroinvertebrate populations (Tennant and Loch, 1979), and less severe effects of this kind are forecast to extend into the upper Poplar River mainstem.

Parametric Summary. Because of the largely ponded nature of the Poplar drainage streams in the northern parts of the basin in Montana, these waters typically revealed naturally low current speeds during the warm weather and non-runoff periods of maximum vegetative growth, and as a result, any further reductions in the river's velocities during this season would be expected to have only a small impact on the aquatic plants. Such an influence would probably involve some changes in the floral compositions of the more currented stream sectors, and it might also possibly involve a relatively trivial increase in macrophytic abundance with the lowered velocities having a greater beneficial effect on the emergent association than on the underwater forms.

In opposition to the velocity, any marked declines in river depth should have a major influence on the hydrophytic communities with an increase in the emergent grouping compensating for a decline in the abundance levels of the submersant plants. This alteration will be seen as a further encroachment of the out-of-water taxa towards the center of the channel with a corresponding decrease in underwater abundance towards the near shore locations, and a very slight drop in overall plant canopy cover might accompany such successional changes in those river sectors that happen to move from a submersant dominated to an emergent dominated macrophyte assemblage. The vegetative effects of such depth reductions will be observed first and will be most distinct in the shallower waters of the basin streams.

Furthermore, if a siltation of the streams should also happen to occur in conjunction with the other morphometric alterations stemming from the Cookson impoundment, then additional pronounced effects would be expected to arise with reference to the macrophyte communities of some if not all of the stream sections in response to this change to a finer-grained substrate composition with the assumption of a lower substrate reference number. In general, a marked increase could develop in the biomass and canopy cover-density levels of both the emergent and submersant associations and in the abundances of the total plant congregation if the substrate change to a silt and muck texture should turn out to be quite pronounced in a reach. But a proportionately smaller enhancement of the aquatics will be obtained if the substrate alterations are not very distinctive. For example, slight declines in the substrate indexes of stream segments with already low reference numbers and a high botanical presence will probably not elevate the macrophyte canopy covers of these particular river sectors to any overly obvious degree.

In addition to the direct influence of the spring freshet and other storm events on the rivers' aquatic vegetation, the lowering of these runoff magnitudes will not only lessen the direct impacts of scouring and bedload movement, but it will also tend to enhance the likelihood of a general siltation of the stream bottom. However, because of the sediment trapping action of the Coronach Reservoir, this added silt deposition will most likely take place in a gradual fashion over an extended period of time so that the effects of the reduce widths, depths, current velocities, warm weather flows, and runoff flows on the plants will probably become more immediately evident in the waters than those stemming from the substrate factor. Furthermore, the development of an increased stream clarity and a warmer spring temperature should be rapidly reflected in the structure of the communities. But the eventual achievement of a silt-muck substrate will undoubtedly be seen as a greater force for elevating the floral abundances of a presently coarse-grained Poplar reach than the impetus that might be derived from any alterations in the other physical aspects of the rivers.

Segment Comparisons. In view of the fine-grained substrates and the high plant abundances that were uncovered in the upper East Poplar River during this present survey, any further lowering of the substrate indexes of these reaches through the next several years will probably not enhance plant canopy covers to any marked extent. Instead, a submersant to emergent succession in response to the reduced,post-impoundment depths of the stream with a gradual encroachment of the out-of-water plants towards the center of the channel should be the most distinctive time-related vegetative change that occurs in this upper portion of the river. In contrast, macrophytic abundance elevations in the lower East Poplar and the upper Poplar mainstem with their presently coarse substrates and relatively low canopy covers could become quite obvious in association with any significant declines that might develop in the substrate reference numbers of these down-drainage positions.

The submersant to emergent changes in the lower East Poplar and the upper main river in response to any reductions in stream depth will probably not be too distinctive until an adequate siltation of the streambed is eventually established, and these substrate alterations will conceivably take place over a large number of years. Thus, depth appears to be a more crirical change-inducing variable in the basin than substrate on a short-term basis, and the effect of a lowered water level will be first seen in the upper East Poplar where it is projected to have a fairly immediate impact with substrate having only a minor upstream influence that occurs over a longer expanse of time. However, a substrate-related vegetative alteration would appear to take prededence over one that is associated with depth in the other parts of the Poplar drainage, and all of the community variations that are induced in these segments will have to be developed across an extended period of years because of the time that will be required to produce an adequate siltation of the coarse-grained stream bottom of these locations.

Quantitative Aspects

Depth. An attempt has been made to quantify the critical water depths, substrate reference numbers, and current velocities at which the projected macrophyte abundance enhancements and the submersant to emergent successional alterations might take place in the Poplar streams subsequent to the occurrence of the various physical changes that should become manifest as result of closure of Morrison Dam. The quantitative approach that was used involved the calculation of canopy cover (WCC) weighted mean depths, substrate indexes, and current velocities for each of the two associations and for the total plant community by isolating and using the data from the ten sectors that showed the highest canopy cover percentages for each of the separate cases. These optimum physical values are listed in Table 26 as are the ranges that were derived from the ten high abundance sectors of each of the plant groups.

In the case of depth, high plant abundances were not obtained with water levels much over 2.2 feet. However, high submersant canopy covers were measured in a depth range between one and two feet when the other physical factors were suitable to plant growth, and an optimum depth of around 1.6 feet was calculated for the underwater macrophytes. High emergent abundances, in contrast, were obtained through a much shallower depth range between 0.1 and 1.1 feet with an optimum water level for the out-of-water plants at only about one-half of a foot. Because of the action of a biotic abundance compensation between the two associations, high total emergent plus submersant canopy covers were obtained through a comparatively wider range of depths between about 0.2 and 2.0 feet which closely covers the optimums and the ranges of the two component associations. In addition, an optimum depth for the total community was calculated at about one foot of water which is approximately midway between the optimums of the two subset assemblages.

The above relationships suggest that a depth value in the vicinity of one foot should be the critical stream water level for establishing the dominance of one association over the other at any stream location. That is, as depths begin to drop below one foot, the emergent plants would tend to replace the underwater forms without any marked alterations in the community's total canopy cover percentages if the substrate features should happen to be amenable to such a vegetative change. But with depths above one foot, the submersants would then be the dominant macrophytic group.

Substrate and Current Velocity. In the case of substrate, a fairly low plant abundance might be expected when the substrate indexes are in excess of 2.7 units, and extremely low canopy covers were noted when the indexes were above the 3.5 level. But at the appropriate depths, high submersant canopy covers were typically obtained when the index fell below 2.7 units with an optimum value of 1.56. However, high total canopy covers were not measured in the borderline 2.25 to 2.7 index range because of the coarse-grained restrictions that were imposed on the emergent forms. The out-of-water plants were seen to be more sensitive to substrate than the submersants with a distinctively lower emergent optimum of 1.14 units, and high emergent canopy covers were observed in the shallower waters only when the substrate reference number was observed to be below a 1.75 value.

As a result of these features, the occurrence of a high plant abundance at a substrate index above 1.75 units was primarily related to the

Table 26. Optimum mean water depths, current velocities, and substrate index numbers and the optimum physical ranges for the emergent and submersant macrophyte associations of the Poplar River drainage and for the streams' total emergent plus submersant plant community.

Plant Groups and Statistics	Depth (feet)	Current Velocity (feet per second)	Substrate Reference Number
Emergent-Mean	0.51	0.006	1.14
Emergent-Range	0.14 to 1.13	0.00 to 0.07	1.00 to 1.76
Submersant-Mean	1.64	0.055	1.56
Submersant-Range	0.99 to 2.12	0.01 to 0.22	1.00 to 2.67
Total-Mean	1.04	0.031	1.27
Total-Range	0.23 to 1.95	0.00 to 0.13	1.00 to 2.24

underwater macrophytes, and a submersant to emergent succession would not be expected to be very pronounced in this higher index range even in the shallower river locations. Therefore, in the reaches with the coarser-grained stream bottoms, the substrate reference number would have to drop to below about 2.25 units at depths above one foot in order to observe a high submersant and a high total plant abundance level with a low emergent reading. The substrate index, in turn, would have to drop to below about 1.75 units with depths at less than one foot in order for a high emergent canopy cover to develop in a stream section in accompaniment with a low underwater plant rating.

Similar to the substrate factor, the emergent macrophytes also appeared to be more sensitive to current speed than the submersants as is suggested by the feet-per-second numbers in Table 26, and the occurrence of the lower velocities that are below 0.1 of a foot per second should ensure the establishment of emergent vegetation when all of the other factors are agreeable to an out-of-water ecesis. This number is about two-times as high for the underwater plants with the submersants more commonly related to the higher velocities than the emergent forms. But current speeds at the low magnitudes that were observed to characterize the Poplar drainage streams do not appear to be sufficient to act as a major restrictive factor to the basin's plant associations, and the streams' velocities were inadequately high to totally negate the establishment of hydrophytic vegetation in a river reach.

Hopefully the opportunity will eventually arise through the next several years to repeat the Poplar aquatic macrophyte inventory so that the impoundment-related botanical changes that do actually occur in the region's waters can be directly documented via the appropriate inter-inventory data comparisons, and this review should include a reassessment of the influences that might be exerted by the various physical factors of the streams such as their adjusted current velocities. The depth and width reductions of the streams during the low flows of the Poplar drainage will probably be much less than the physical changes of this kind that were predicted with the rivers at a bank-full discharge capacity. As a result, the effects of these morphometric alterations on the plant communities should be much smaller than what might be projected on the basis of the bank-full data since a low flow hydrological regime is present through most of the growing season. Therefore, the exact vegetative influences of the depth and width alterations cannot be ascertained at this time because of the lack of information, and these aspects will have to be determined via the comparisons that can be made after the completion of the follow-up work in the region.

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